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Learning Mathematics in Car Parking Lots: A Case for Promoting STEM Education Learning Activities

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Abstract: Real world applications have the potential to bring learning mathematics to a new, exciting, even authentic level for students. Based on the tenets of experiential learning theory students learn through meaningful and collaborative experiences with the dimensions, usage, regulations, and design of local parking lots. Initially conducted with a small group of students, the resulting enthusiasm from students and teachers, additional ideas and activities were created. The activities outlined here use arithmetic, algebra, geometry, trigonometry, and statistics into studies of architecture, engineering, and other areas that depend on mathematics at their core. The premise of these activities comes from a creative approach of teaching students, using an actual structure to understand how mathematics was used to design it and how mathematics can be applied to improve it. At each stage, the process goes from data to knowledge, to information, and finally to wisdom. Students from middle school to community colleges and above can use these activities to apply mathematics directly in their community.

Key Words: Experiential learning, Constructivist Theory, Social Theory, teaching methods, active learning, mathematics, statistics, science, STEM education, arithmetic, algebra, geometry, real-world applications, problem-based learning, college mathematics, middle school mathematics, high school mathematics

I – Introduction

Solving math problems over and over within the classroom or through homework certainly builds skills and practice makes perfect. However, bringing mathematics to life and showing its application in the real world can spark interest and excitement among students in a mathematics classroom. Learning, after all, is about making connection [1] through experiences (doing) and meaningful reflection (thinking) ([2], [3], [4]), and math is no exception. Learning mathematics is easier "when the learner can connect mathematical operations and concepts to solving problems in the real world" [5]. This understanding serves as a guiding mantra to bringing that excitement to the math classroom. This then creates the need for educators to find activities that connect numbers and space through specific mathematical concepts to real world situations within the time constraints of the classroom and lecture hall. After all, today

> *Mathematics is widely used in business, [engineering, technology], finance, and the biological, social, and physical sciences, from developing efficient production schedules for a factory to mapping the human genome. Mathematics also plays a role in determining interest on a loan from a bank and the cancer risk from a pollutant, as well as in the study of falling objects. [6, p. 1]*

Mathematics also has an essential role in designing and constructing buildings, bridges, tunnels, canals, roads, sport fields and tracks, to name a few. Additionally, everything in nature and art require the fundamental ideas of arithmetic, algebra, geometry, trigonometry, calculus, and statistics, and are clearly embedded in numbers and space. In this set of learning activities students use car parking lots in and nearby schools and the cars parked in them to actively engage in collecting, classifying, analyzing, interpreting, and inferring data and information related to identified variables with categories, sub-categories, and beyond. In doing so, students learn the value of numbers, space, pattern, sampling, and logical reasoning, within the realm of learning mathematics, and apply what they have learned in different situations that they might encounter in their daily life. The focus is on visual, practical real-world situations and conditions with relevant contemporary application. By making student experience in the parking lot more educationally memorable and meaningful, they have the opportunity to build a deep, conceptual understanding of mathematics, and its applications, by learning problem-solving strategies, theories, and concepts in relevant, practical, and exciting approaches. These activities are uniquely crafted to deliver learning experiences that students simply cannot get in a classroom or a lecture hall alone. Imbedded in all suggested activities is the aim to make students' learning experience academically comprehensive, engaging, insightful, and inspirational.

Safety Note: While many of these activities describe students going directly to the parking lots, instructors must consider the age and characteristics of their students. Many activities could be done from pictures, research, or perhaps online videos. If going to parking lots, do not take students to parking lot facilities during the early morning hours before 9:00AM, during lunch hours from 12:00 -1:00 PM, and during the time most people leave work, between 5:00-6:30 PM. During these specific times the traffic in and out of the parking lots may often be heavy and busy. At all times, the safety of the students must be the priority.

II - Experiential Learning Theory

Experiential learning theory incorporates both social and constructivist theories, encouraging students to create their understandings based on experiences and effective reflection on those experiences. These experiences need to be meaningful and often include other individuals with whom each learner can discuss their concepts and together, the group can build understanding, raise new informative questions, and construct a new knowledge. Professor David Kolb (1984) stated that learning is the process whereby knowledge results from the combination of grasping experiences and transforming those experiences through meaningful reflection. Within mathematics, experiential learning activities can also answer the often-asked question of when someone would ever use these skills. Development of this concept has occurred over several decades.

Using experiential learning has been an idea in education for a long time ([2], [3]). In the 1990s, this was often termed problem-solving learning and was promoted by educators as a new wave in education [7]. These strategies were to move from conventional academic instruction to a method where students would learn by doing and continuously reflecting on those experiences, thereby developing skills and true understanding [4, p. 6]. This new method of instruction has been resisted by teachers and instructors for many years. For example, the lack of experiential learning conducted within the classroom was the focus of a study by Gainsburg (2008) where it was found that teachers in secondary mathematics courses had several reasons for not including such activities. These reasons encompassed time constraints, curriculum pressures, and size of the class. This study implies that while teachers see the benefits of experiential learning, these activities are seen as taking too much time and being somewhat inconsistent with the curriculum they are required to cover [9]. Further, experiential learning is built upon the foundation of inter-disciplinary, multi-disciplinary, and constructivist learning. Many, if not most teachers and institutions see value in continuing a single disciplinary approach in teaching. Citing Wurdinger (2005), Michelle Schwartz (2012), Research Associate, for the Vice Provost, Academic at Ryerson University, illustrated:

> *Experiential methodology doesn't treat each subject as being walled off in its own room, unconnected to any other subjects. Compartmentalized learning doesn't reflect the real world, while as the experiential classroom works to create an interdisciplinary learning experience that mimics real world learning [10, p. 24]. Similarly "experiential learning is aligned with the constructivist theory of learning" in that the "outcomes of the learning process are varied and often unpredictable" and "learners play a critical role in assessing their own learning" [10,, p. 69]. How one student chooses to solve a problem will be different from another student, and what one student takes away from an experience will be different from the others. [11, p. 1]*

Because of issues and factors such as these, experiential learning has been enhanced in some studies with the inclusion of collaborative activities. For example, cultural intelligence was increased within a collaborative, experiential learning activity among second language students [12]. Combining experiential learning with collaboration was perceived to increase students' knowledge, motivation, and confidence. Others (e.g., Kolb 1984) have tried to match and integrate student's learning styles with the experiential learning.

Even with younger students, for example in elementary and middle schools, experiential learning and applications play a key role in bringing math to a more practical and understandable level. For example, at Stephen F. Austin State University, pre-service teacher candidates present a mathematics career carnival for local elementary school students to demonstrate how math is applied in real careers. For example, students act as pool architects to determine the perimeter and volume of a pool, a travel agent determining costs, and a veterinarian medicine levels based on size and type of animal [13]. Another example can be seen in *Mathematical Journey Through the Human Body*, a set of workshops conducted by Cherif, Gialamas, and

Verma (1997) by studying math concepts through the measurable exploration of the human body. Students collected data and then transformed these data into information and meaningful knowledge, through which they understood intended concepts more deeply, mastered the needed content and skills, and successfully applied what they learned in different contexts [14].

These inspiring examples fueled an impromptu lesson to various school students using a local parking lot and the cars parked within that lot. The excitement generated among the students based on this exercise was inspiring. Using that experience as a springboard, the example was extended to encompass basic mathematics, algebra, and statistics for students at varying ages and skill levels. It also inspired the learning of science concepts, engineering, architecture, technology, ethics and human behavior, and civic engagement and social responsibilities. Teachers understand that students are able to overcome challenges of learning difficult subjects, for example statistics, by being in an environment where group activities allow the students to learn from each other, have hands-on exposure to familiar material, and be surrounded by a friendly atmosphere [15].

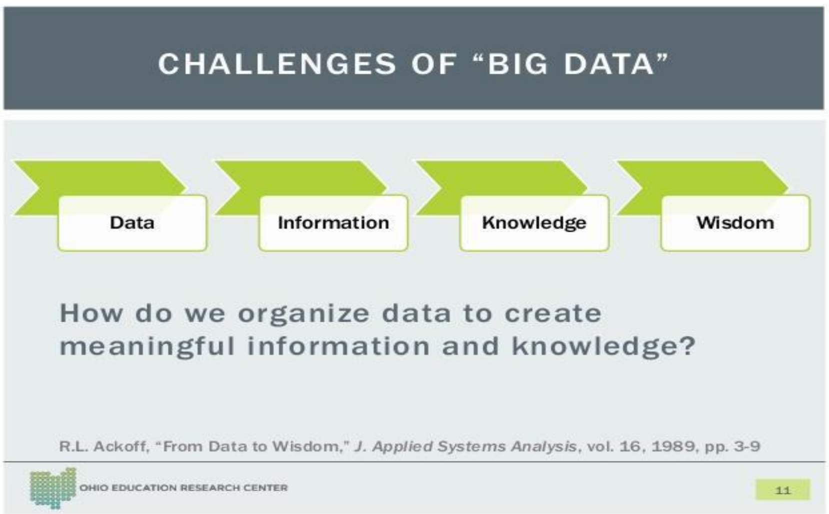
Experiences alone, however, will not directly lead to learning. John Dewey (1983), who extensively studied the essential role of direct experience in effective learning through thinking and doing, strongly argued that not all experiences are genuinely or equally educative ([2, p. 25]. For a given experience to lead to significant learning, it must be designed with educative outcomes in mind and must be guided through continuous immediate feedback when needed. Therefore, each activity described in this article was designed to meet the characteristics of experiential learning as defined by Chapman, McPhee, and Proudman (1995) [16], (See Appendix 6).

A. From Data to Wisdom

In the learning activities, students initially engage in collecting a variety of numerical data and information to be used as raw material and starting points to explore, discover, and achieve the intended learning objectives. Ackoff (1989) defined data "as symbols that represent properties of objects, events and their environment" [17]. Others see and look at data as "a unique set of symbols representing a perception of raw facts" [18]. While Liew (2007; 2013) explained that the main purpose of data is "to record activities or situations, to attempt to capture the true picture or real event" ([19], [20]). This means that data itself inherently contains no meanings simply because pure data in a database does not have any inherent stature. On the other hands, information is often seen as "Data" with meaning because it has inherent structure [21].

Students need to understand the concept of data mining that is the process of recognizing and identifying concentrations, patterns, connections, etc. The pattern recognition refers to "the application of structure to the otherwise structure-less data and 'distillation' implies that a large amount of data can be turned into a smaller 'conceptual amount' of information" [21, p. 12]. This understanding begins Ackoff's (1989) process that questions how to approach the challenges of 'big data' (Figure 1).

Figure **1**
From Data to Wisdom (Ackoff, 1989)



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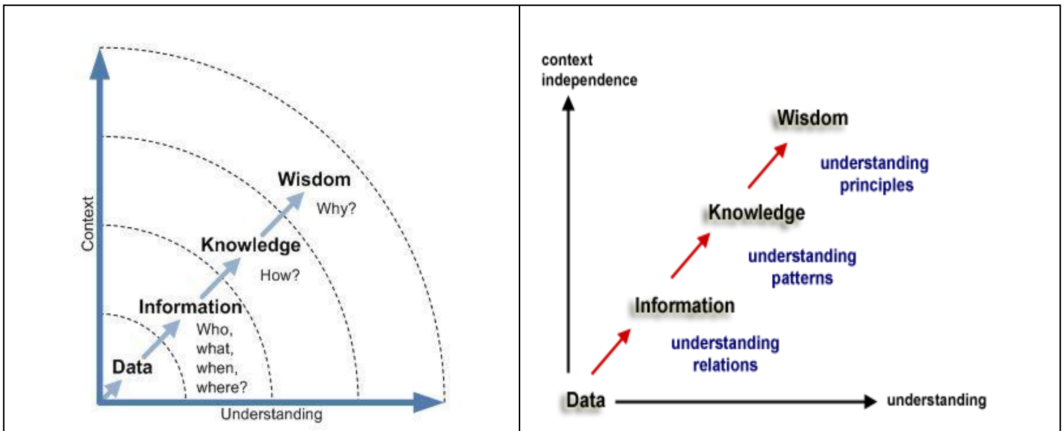
The transformation of information into knowledge starts with the accumulation and assimilation of multiple pieces of meaningful information that leads to the creation of meaningful knowledge. This means that the construction of knowledge requires the continued eliciting flow of meaningful organized body of appropriate pieces of information with some fashion of structural relationships ([22], [23], [21]).

In this set of activities, students learn and use the skills of gathering data, transfering data into useful information, transforming that information into knowledge, and using that knowledge as tools for decision making and problem solving [17]. Further, students acquire and construct new knowledge, expand their interests, and most importantly build their curiosity into new ideas, questions, and applications [1]. These skills follow Ackoff's design (Figure 2) for general understanding of a topic when applied to mathematical learning

Figure 2
From Data to Wisdom (Ackoff, 1989)



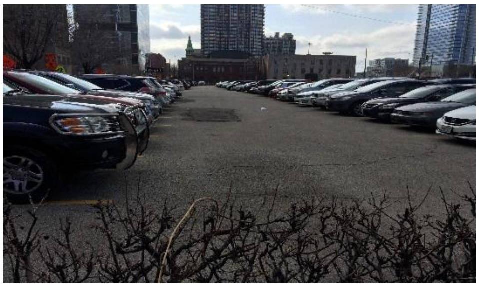
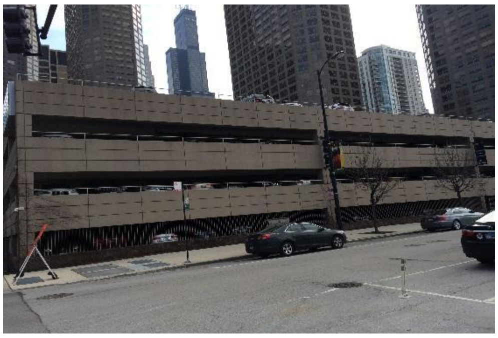
General Understanding | Math Application

B. Parking Lot Concept

This set of activities can encompass arithmetic fundamentals (including the arithmetic of whole numbers, fractions, decimals, order of operations, ratios, and proportions), or pre-algebra concepts (including percent, signed numbers, applications of introductory geometry, and measurement) and beyond into statistics, an introduction to polynomial expressions, solving linear equations, linear relationships, and square roots. While it depends on which school level or community college being taught, parking lot facilities can be a good starting point to introduce students to concepts of elementary algebra and basic geometry and the principles of mathematical reasoning including investigations of properties and relationships of two- and three-dimensional figures such as angles, triangles, circles, polygons, convex sets, areas, volumes and similar figures. Most importantly, this activity demonstrates for students how these skills can be applied in the real world and are used more often then they might think.

Parking lots are available everywhere including at schools or near schools that give them the advantage to be used as a desirable learning environment. They are in different shapes, designs, sizes, floor-levels, covered or not covered, heated or not heated, with windows or no windows, etc., (Figure 3). They are governed by municipal and city rules and codes that regulate for example, the minimum width of the driveway, the maximum length of parking aisle, the minimum location of support columns to the parking aisle, the flow direction of internal circulation, the minimum floor heights, the minimum setback of the underground and subterranean parking structures, minimum and maximum parking floor and ramp grades, ramp transition, ramp widths, minimum number of elevators in parking lots with 3 or more stories, minimum lighting and their footcandles for various areas (Appendix 2), to name a few. Embedded in all these matters is a wealth of numbers, space, and information.

Figure 3
Parking lots come in different designs, ships and forms

As Ben-Joseph (2012), a professor of urban planning at M.I.T stated parking lots are the strongest sign and reminder of our automobile-oriented society.

Furthermore, parking lot facilities contain so many different types and sizes of cars that can be used statically to generate data and information which in turn can be used to teach and learn various types of desirable skills. For example, cars can be statistically assorted by various characteristics and then summarized through tables such as shown in Table 1.

a. Car-made by maker or manufacturing company.
b. Colors of cars
c. Size of cars: Small-size passenger, medium-size passenger, full-size passenger, mini-van, full-size van, utility, semi-truck, truck
d. Cars by type of services; passenger, utility, truck
e. Cars with 2-doors and with 4-doors
f. Cars with and without wheel covers
g. Cars with wheel covers:
    i. 3-star shape
    ii. 4-star shape
    iii. 5-star shape
    iv. 6-star shape
    v. 7-star shape
    vi. 7+ star shape
h. Car plate registration - I
    i. In State
    ii. Out of State
    iii. Temporarily
    iv. International
    v. Diplomate
    vi. Government

i. Car plate registration - II
   i. Private
   ii. Commercial
   iii. Government

Table 1
Example of the relationship between variable, category, and subcategory

	Variable	Category	Sub-category
	Car Size	Passenger cars	Mini-size
			Small size
			Med-size
			Full size
		Transportation Cars	Mini-van
			Full-size van
			Mini-bus
			Med-size bus
			Full-size bus
		Utility Cars	Small-size truck
			Med-size truck
			Full-size truck

III - Pedagogical Approach

The activities and exercises available require teacher guidance and motivation. Start by having class discussions to identify the variables that students might look for when they go to a parking lot facility and list them down. Discuss the educational merit of each one of them and keep only those that the teacher and the students think are educationally worthwhile to methodically explore and statistically study and analyze. Then ask each group of two students to select one or two variables for which they will collect data to study, analyze, and apply (for example, color of cars and size, etc.).

Students work in groups to discover mathematical concepts and principles, embedded in statistical numbers, create meaning out of them, and try to apply them in real situations. By engaging in these learning activities, students learn new concepts, re-enforce their existing understanding of learned concepts, and sharpen their skills of applying learned concepts and principles in different setting and under various conditions. The activities require the use of paper, pencils, calculators, measurements, data collection, plotting and graphing, analytical techniques, and cooperative and collaborative group work. It is designed to allow students to explore specific topics in more depth both individually and in groups.

The objectives are for the students to:

1. Practice their basic numerical mathematical skills they already have and those which they will learn or re-learn to solve a given problem.
2. Learn and practice the basic statistical skills, including data plotting and graphing, analytical techniques, statistical thinking, reasoning and interpretation.
3. Make the connection between a given concept, its associated skills, and its applied practice.
4. Develop communications skills and problem-solving skills.
5. Develop collecting, organizing, analyzing, inferring, and communicating information skills.
6. Develop mathematics thinking and literacy as well as statistical thinking and literacy.
7. Foster active learning by developing concepts and analyzing data, and making sense out of the data.
8. Develop data literacy by realizing and understanding that data and numbers by themselves inherently contain no meaning without categorizing and analyzing them to discover hidden patterns. It is then that thinking and reasoning can be used to interpret and come up with ideas and conclusion, thus making sense of the data. These efforts build on knowledge, create structures, and uncover the hidden secrets of the ways in which nature works ([24], [25]).

Finally, in working in parking lots and their content, students follow and apply Ackoff's (1989) steps to bring the Data to Knowledge.

Data: The first step would be for these students to collect data from the parking lot. Ideally, the parking lot would have various levels and students could work in groups with each group being assigned to one level of the parking lot. They could collect information based on the cars within the parking lot such as manufacturer, color, number of doors, to name a few.

Information: To transfer these data into information, students would be asked to organize their information into tables and graphs. Each group would be responsible for determining the most appropriate graphs to use for the information they are trying to display, for example line, pie, bar, column graph, etc. (Table 2).

Knowledge: Based on the tables and graphs created, each group should draw conclusions about the cars on their level of the parking lot. Are certain manufacturers more population? Are there colors that are selected most often by owners? Are there patterns between manufactures and colors or between the number of doors and colors? Groups can create additional tables and graphs as they analyze the data and look for patterns to the information.

Wisdom: Finally, the groups should draw conclusions based on the information they have collected. What could this information tell car manufactures? How could this information impact decisions by car dealerships? Why might customers in that area be selecting the most population car manufacturer, color, or number of doors? In other words, what demographic or regional information might be influencing some of these outcomes? For example, if most cars had four doors, this might imply that the area includes more families with children. Finally, how can this information influence the design of future parking lots in the area? Should parking spots be larger or smaller? Should pricing deals be made with specific manufacturers?

Younger students can focus more on the graphs and tables, reflecting the lower level Bloom's taxonomy questions. They would be focusing on the discovery of patterns in car purchases. Older students can expand this example into statistical analysis, including hypothesis testing, inference and conclusion.

IV - Parking Lot Facility Activities

Following learning activities have been tried and perfected in various school levels of mathematics and math related courses. The activities grow with mathematics knowledge and can eventually be used in more advanced courses with or without further modifications. It can be best to start with an assignment focusing on ensuring all students know how to plot and make graphs and charts before physically taking students to explore and investigate parking lots. The following assignment can prepare students to be cognitively confident in engaging in all the subsequent learning activities.

1. Homework Assignment: Why Students Need to Know How to Plot and Make Graphs and Charts?

Making and interpreting graphs and charts are cognitive skills that provide students with multiple opportunities to visualize and investigate data in various ways. However, students not only need to learn how to plot and make graphs and charts, but also how to extract the meaning from existing charts or graphs they encounter on daily bases. Today's students need these two related skills (making and extracting) especially for those students who would major in the social sciences and history disciplines among others [26]. After all, gathering, collecting, and interpreting numerical information is a necessary skill for better math understanding and many other important analytical thinking and reasoning skills [27].

> *As students organize and analyze data, they ask meaningful questions and dig deeper to solve problems. Moving beyond simply memorizing facts, students acquire the skills of reasoning, inquiry and communication. Building data literacy makes for a richer, more meaningful experience.* [25, ¶. 2]

Critical thinking and problem solving are two major goals in teaching mathematics. Faculty need to stimulate critical thinking and problem-solving skills to improve academic performance [28]. The ability to make graphs and extract the meaning from graphs are a way for students to develop problem-solving skills with the use of data. Mastering interpretation of graph develops the critical thinking skills needed to communicate the results for decision-making [29].

To start a rich discussion on graphs and their uses, students are provided a copy of Table 2, which contains a list of graph and charts types initially without their use and purposes. Students are asked to conduct research to find the appropriate use for each graph and to provide examples of an application for each type. In the class, open discussion is conducted with all students to explore the definition, meaning, and an applicable example for each of the graph types. There are numerous benefits to this activity and discussion. First, both academic and real-world research often starts with the gathering and collecting of data and information, which then needs to be appropriately interpreted in meaningful ways. Second, students develop a shared vocabulary to effectively communicate with each other and with their teachers during the learning process. Students are more seriously engaged and active when they all use the same vocabulary during the learning processes. Third, students begin to understand the different types of data used in each graph. This discussion shows students that different data types require different graph types. Fourth, students learn to verbalize using subject-matter vocabulary, stimulating the critical thinking skills needed to make decisions about data when using the appropriate graph. As with learning a foreign language, it is important for students to speak aloud the specific vocabulary needed to describe the graphs and to provide appropriate examples for use. Finally, the discussion should go one-step further by having students provide examples of business-specific questions and decisions that could be aided with specific data and graphs.

Table 2
Various Types of Graphs and Charts and Their Better Use

	Graph /Chart Type	Use This Type to:	Applicable example:
1	Line	Show tends over time (years, moths, and days, or categories)	
2	Bar	Visually compare value cross a few categories when the chart shows duration on the category text is long. It is an ideal way to analyze distributions and measurements of central tendency such as mean, median, and mode.	
3	Pie	Show populations of a whole by illustrating percentages of a whole or to numerically represent a category of facts with distribution of values within one field of a database. Use it when the total number is 100%.	
4	Bubble	Show the relationship between sets of values.	
5	Column	Visually compare values a cross a few categories	
6	Area	Show trends over time (years, months, days) or categories. Use it to highlight the magnitude of change over time.	
7	Combo	Highlight different types of information. Use when the range of values in the chart varies widely or there are mixed type of data.	
8	Pivot	Graphically summarize data and explore complicated data.	
9	Venn	Show relationships between mathematical sets by identifying and showing the commonalities and differences between things, people, places, historical events, ideas or physical attributes based on their characteristics.	
10	Axis or Scatter	Investigate correlations and examine relationships between the variable.	
11	Stack or sorting bins	Show the distribution of values within one field of a database by representing a range of data for one variable.	

Table 2 lists the graph / chart types. The second column shows examples of uses for each respective graph that the students should discover with their research. The third column is for students notes for the discussion of appropriate applications for each type.

This exercise helps to develop problem solving skills by allowing students to understand the importance of using appropriate graphs based on the type of variables, thus an understanding of multiple data type. Discussing the types of data and providing further questions by looking at the results emphasize critical thinking skills.

2. Activities Focused on Design of Parking Lot

In this learning activity students engage in a discovery-learning approach to get to know their identified parking lot facility better. They will study and explore its design, physical structure, accessibility, service facilities, operation and management, etc. While any parking lot can be used for this activity, a parking lot with more than one floor levels works better. In this activity students will observe the parking lot and begin to understand the basics by making sketches and collecting qualitative data. Through observations the student will be able to answer these questions and become more aware of the distinct qualities of what the parking lot offers. Asking students to make sketches can be instructive as Newcombe (2013) convincingly argued, "active sketching enhance engagement, deepens understanding, requires reasoning, force ideas to be made explicit, and supports communication in work groups" [30, p. 30].

Students can first focus on information and variables to be collected such as:

1. Where is this parking lot facility located in reference to the school?
2. How many floors does this parking lot have?
3. What are the dimensions of the main floor of this parking lot? What is the total area of the main floor of this parking lot?
4. How many spaces (spots) designated for parking cars in the main floor of this parking lot?
5. When is this parking lot most busy during the day?
6. What are the average dimensions of a given space (spot) that is designated for parking a car in the main floor of this parking lot? (e.g., length and width)
7. What is the average total area of a given space (spot) that is designated for parking a car in the main floor of this parking lot?
8. How many entrances and exits does this parking lot have?
9. Are the exits and entrances designed and designated for both – to enter and to exist – or are they designated and designed to enter only and exit only?
10. What is the minimum driveway width and the maximum parking aisle length in this parking lot?
11. How many support columns does this parking lot have and where are they located in each floor?
12. Are cars intended to travel the lot clockwise or counter-clockwise?
13. What is the shortest floor height?
14. What is the width of each ramp in this parking lot and does each ramp contain transition zones at the top and bottom of the given ramp?
15. Does the parking lot have mirrors for sight distance in each floor and passenger elevators?
16. Is the internal circulation of vehicles in this parting lot structure designed to flow
17. Is this parking lot covered, uncovered, or both?
18. Does this parking lot have a gated entrance(s), gated exit(s), a personal guard at the gate, or an automatic electronic gate?
19. Are all the spaces design for:
    a. One size fits all?
    b. Large-size vehicles (about 6 feet wide and 17-18 ft long)?
    c. Small-size vehicles (about 5 ft wide and 14-15 ft long)?
    d. Intermediate dimensions (too small for large vehicles and too large for small vehicles)?
    e. Various dimensions to fit all types of vehicles (size, length, etc.)
20. Does it have enough light both at day and night?
21. What type of materials are the floors of the parking lot made of?
22. What are the dimensions of the width and the length of stalls, and the width of aisles, the angle of parking, and the radius of turns?
23. Does this parking lot facility provide services such as:
    a. Gas services?
    b. Access to electrical charges for electric cars?
    c. Car wash?
    d. Limited car service and repair

24. How accessible is the parking lot to the surrounding routes?
25. Is it a free of charge or people must pay to park their vehicles? If "must pay", is it hourly pay, daily pay, monthly, or yearly? Is it for the whole day, or free at night?
26. Is it accessible to people with various types of disabilities?
27. Is it equipped with access to free phone for safety and emergency?
28. Does it have water fire-hoses both in the ceiling and walls?
29. Does this parking lot provides additional services and satisfy needs to the community such as space for farmers' markets, spontaneous games of street hockey, tailgating, or teenagers 'illicit nighttime parties, to name a few? [31].

Based on the data and information collected, students can begin to address many questions related to the design of the parking lot. For example:

1. Calculate the total areas designated to parking cars in reference to the total area of the whole main floor of this parking lot?
2. What percentage of the lot is allocated to parking spots compared with aisles and entrances?
3. If the lot were filled all the time, what is the highest revenue possible?
4. Based on the usage and pricing, is this parking lot encouraging short-term or long-term patrons to this lot?
5. What percentage of spaces are designed for different sized cars and how might that percentage have been determined?
6. How could the lighting impact usage of the parking lot?
7. What percentage of the lot's space is taken by other services? What revenue might be necessary to support that allocation?
8. If you have the opportunity to re-design this parking lot facility, how would you re-design it? Explain why?
9. What have you learned from engaging in this learning exercise?

<u>Making the Connection to Other Disciplines</u>

There are a variety of questions or situations that could be posed and then addressed throughout the activities described in this paper. The question or situation would then determine what information should be gathered by students, which variables would be most relevant to that situation, and which analysis techniques would best lead to knowledge, understanding, and decision making. Here is an example of a situation that students could address through these activities.

> Students are asked to take on the role of the owners of a parking lot. A company approaches the owners (the students) to get permission to add "Quick Automobile Services" which intended to provide services to parking lot customers while they are waiting. The services will include oil change, battery charge or re-changing, light bulb change, etc. In order to do so, they need valuable space in the parking lot which means reducing the number of spots currently designated for parked cars. The owners have agreed to give a response in one week and will be considering the business implications along with the safety and well-being of customers. Working with one or two classmates, students are to provide two written responses: one agreeing to the auto services and why, and one declining the auto services and why.

Another example can be by collaborating with teachers who teach art. The data collected allows students to use graph paper and learn to draw the parking lot to scale. This can lead to a beginning conversation about blueprints and architectural design. Diorama can also be created with small cars and additional lot features emphasized.

3. Activities Focused on Cars in Lot

Even though many communities have started to take advantage of existing parking lots and use them, when needed, for many other civic service activities, parking lots are the strongest sign and reminder of our automobile-oriented society. As Ben-Joseph (2012), a professor of urban planning at M.I.T., illustrated, as long as the majority of human beings prefer to get around by cars (whether powered by fossil fuel, solar energy and or hydrogen), the parking lots and their automobile occupants are here to stay. In this activity all students are asked to use these questions as a research and exploration guide for gathering more data and information about the operation and the utilization of the parking lot facility.

1. How many total parking spots are available?
2. How many cars are in the lot currently?
3. What is the size of the cars found in this parking lot (small, midsized, and large)? How many of each of size in the lot? Which one of them the most dominantly and which one of them the least dominantly found in the lot?
4. What types of cars are found in this parking lot?
5. What color are the cars in the lot?
6. Approximately what is the average weight of the lightest and the heaviest car in the lot? (Appendix 3)
7. If possible to identify, how many cars are powered by fossil fuel, solar energy, hydrogen, or combination of more than one source?

Using these data, students can conduct analysis and research to determine many inferences and conclusions about the cars in the lot.

1. Calculate the percentage of the most occurring color of cars in the parking lot.
2. Calculate the percentage of the least occurring color of cars in the parking lot.
3. Calculate the percentages of the size the cars in the parking lot.
4. What is the usage of this lot?
5. Based on the distribution of the car sizes, what demographics are likely living in the area of this parking lot?
6. How could the car type determine how the parking lot facility should be designed?
7. If you have the opportunity to re-design this parking lot facility, how would you re-design it? Explain why?
8. What have you learned from engaging and from answering these questions?
9. Based on how many numbers of cars and their sizes and types, predict the total weight of all cars in each floor and in all floors?

<u>Making the Connection to Other Disciplines</u>

Collaborate with teachers who teach geography by allowing students to use their collected data and information to study where the cars in the parking lot were designed and made. Students can then engage in open discussion with their classmates by sharing and discussing their own explanation for the reason behind their findings. These discussions may lead to international awareness of business opportunities.

4. Activities Focused on Accessibility and Designation

All students are asked to use these questions as a research and exploration guide for gathering more data and information about the accessibility and designations in this parking lot facility.

1. Is it a private or a public parking facility?
2. Does it have a passenger elevator? How many in total?
3. It is accessible to individuals with disabilities?
4. How many spots on each level are designated for individuals with disabilities?
5. How many other especial designated spots in the parking lot such as for executive administrators, loading lots, fire-hoses, etc. are there on each level?
6. Is the parking illuminated by electricity generated by oil and fossil fuels energy, wind energy, solar energy, or combination of two or more types of source of energy?

Based on this information, students can consider questions such as the following to focus on the design of the parking lot based on accessibility and designation.

1. What percentage of the number of this type of special designated spaces (executive administrators, loading lots, fire-hoses, etc.), to the rest of the spots in a given floor, and in all the floors?
2. What percentage of the number of designated spaces for individuals with disabilities to the rest of the spaces in a given floor, and in all the floors?
3. Use the information to estimate the percentage of the lot used by accessibility elevators.
4. What types of disabilities were considered in the design of this parking lot?
5. If you have the opportunity to re-design this parking lot facility, how would you re-design it? Explain why?
6. What have you learned from engaging and from answering these questions?

<u>Making the Connection to Other Disciplines</u>

Collaborate with teachers who teach physics by allowing students to use their collected data and information to study and differentiate between energy and electricity, for example illumination (brightness) and watts. Most students get easily confused when asked to differentiate between energy and power, between watts and watt-hours. For example, students need to know and understand that power (P) is the rate at which generated or consumed energy flows and hence in electrical system is measured in units called watts (W) and represents energy per unit time. For example, a 100-watt lightbulb will consume electricity at a rate of 100 watts per hour, and by the same token, a 40-watt-lightbulb will consume electricity at a rate or 40 watts per hour. In the metric system, one watt is equivalent to electricity flowing at a rate of one joule per second which is also equivalent to 3.4Btus per hour [32]. Most students become intrigued by knowing that:

> *A laborer working through the day will put out 75 watts of power. A medium-sized car might consume 100,000 watts. (One horsepower is equivalent to 750 watts, so that's a 286-hp car.) A small gasoline generator puts out 2,000 watts; the Vermont Yankee nuclear power plant puts out 650 megawatts, or 650,000,000 watts.*
>
> [32, ¶. 9].

Students could be challenged by asking them that if “the average onsite energy used for office buildings in the U.S. is 76.3 kBtu/ft2·yr; for single-family detached homes is 43.8 kWh/ft2·yr; for multi-family homes of five-plus units is 49.5; and for mobile homes is 73.4 kWh/ft2·yr" [32] can they predict the average onsite energy use for the parking lot being explored?

V - Making Decisions and Solving Problems Based On Inferences and Informed Conclusions

1. Re-designing the Parking Lot Facility

All these activities can be completed at varying levels of depth. A warm-up activity would combine all knowledge developed through the activities to create wisdom in designing parking lots. Students could be asked: Knowing what you know now about this particular parking lot facility, how would you re-design it and why? Include in your answers: what you like, dislike about its design, location, operation, accessibility, safety and protection, adjacent supporting facilities such as gas station, oil changing services, tire suppliers, etc.

2. Inferences from Community Car Choices

One area of research would be focused on the cars parked within the lot. The type and color of cars provides insights to the types of families in the area, color preferences, and may feed into the design of the parking lots themselves. Using variables based on the cars may be more suited to middle school and elementary students as it is a more straightforward approach. This examples walks students through Ackoff’s (1989) steps of transforming data into information then knowledge and finally developing wisdom based on the findings. Following the general strategy under Pedagogical Approach, these steps would be:

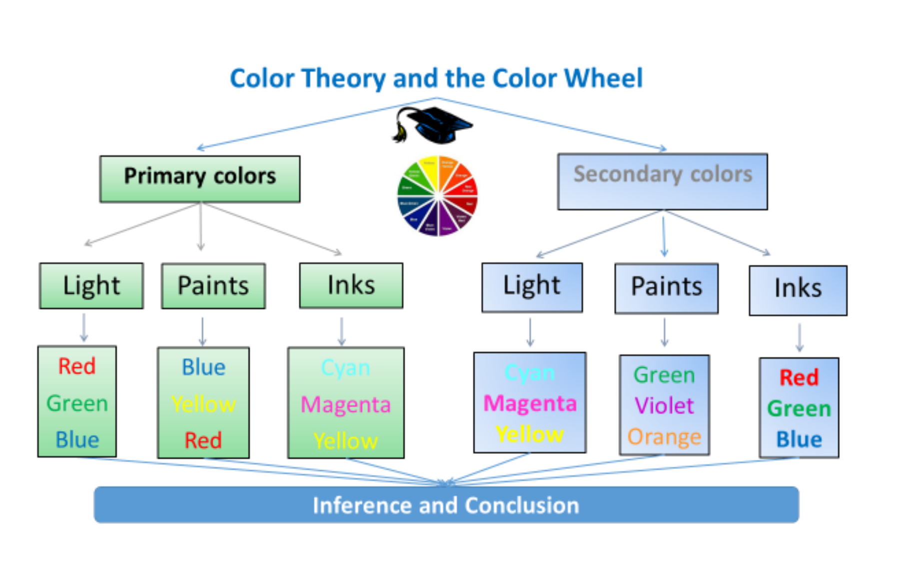
- Data: Students would collect data on the specific type of cars in the lot
- Information: Students would organize the data into tables and graphs
- Knowledge: Conclusions would be drawn about the types of cars that are popular in the community
- Wisdom: Students should describe how these conclusions might impact community members, such as car dealers

<u>Making the Connection to Other Disciplines</u>

Collaborate with science teachers in the school by allowing students to use their collected data and information about the distribution of the color of cars as starting point to explore and study color of light, color of pigments, color theory, primary and secondary colors of light and pigments, color wheels, etc. (Figure 4). In doing so, students could explore why black and white are the most dominated colors among the colors of cars in any parking lot. Or how the color of an object is determined by the color of the light it scatters. Or what role does static electricity play in the process of painting cars, to name a few. For example, “one practical example of some usefulness of static electricity is in paint spraying such as in cars. The parts to be painted are charged with electricity of opposite polarity to that on the paint droplets leaving spray guns, which makes the paint stick” [33, p. 44].

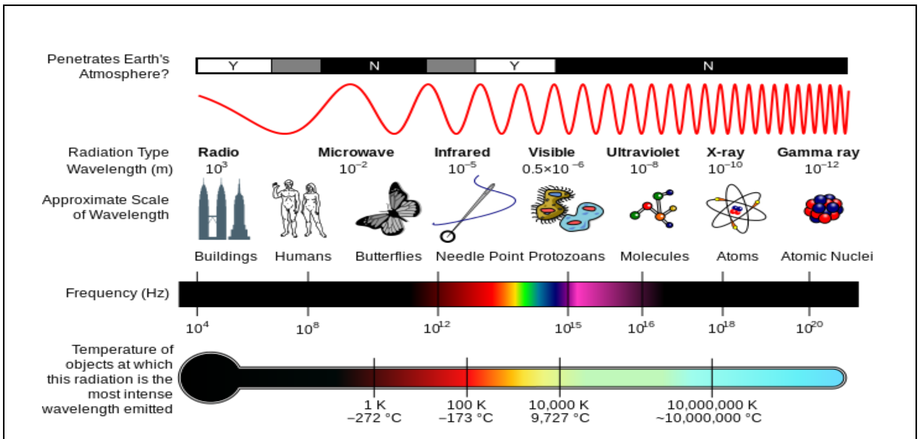
In biology or physics classes, teachers could use the raw data collected by students and ask them about their own favorite car color and why. Then use this as a pathway to ask them about how colors are seen, which could lead to studying the anatomy of eye, the color theory, the Electromagnetic Spectrum of Light (e.g., ultraviolet light, visible light, infrared light, etc., Figure 5). Explain to students how light is energy caused by a combination of electrical and magnetic fields and how those create different colors seen by human eyes. They can also investigate with the students the most abundant color seen in nature and the least color seen in nature and why. Appendix 4 provides additional information about pigmentation and color.

Figure 4
Primary and Secondary Colors of Light, Inks, and Paints

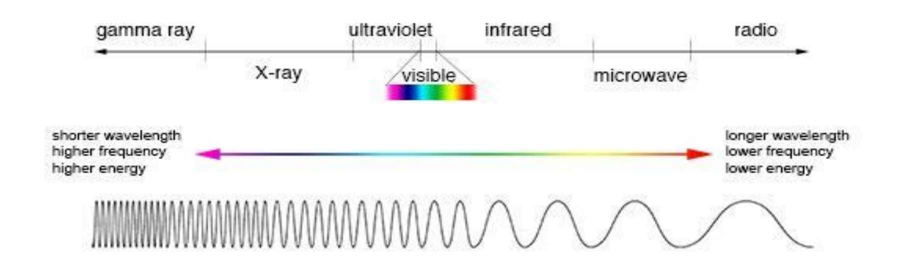


Source: [34], [35]

Figure 5
The Electromagnetic Spectrum



https://en.wikipedia.org/wiki/Electromagnetic_spectrum



https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

3. Doing the Right Thing: Ethics, Morality and Self-Responsibility In Parking Lot Facilities

Car owners everywhere not only need to be courteous and to use caution when parking in the garage, but also to park within the assigned stall lines at all times. Everyone must align their cars to facilitate their neighbors access to adjoining spaces. In civil and democratic society, all drivers are expected to police themselves and to obey the rules and regulations enacted by the city, state, and or the country, and must operate their vehicles with courtesy towards fellow citizens, pedestrians, and other vehicles [36]. Social studies and civics classes could use data and information from parking lots to consider ethical and moral questions. For example, consider cars that pay to park, but end up using two spots. Is this morally correct? Is this ethically appropriate? Is there a role society or law enforcement should play in this situation? (Figure 6)

Figure 6
When Cars Don't Park within the Assigned Lines

Discussion Question:
Should Citizens report to the authorities cars that are not parked correctly in the designated spots?

Governance of Correct Parking

Students could research the state and local laws and regulations regarding parking lot usage to determine if this question has been addressed in their area. If so, students can consider if they believe those remedies to be sufficient and if they would prevent all such issues. They can also consider how citizens might still misuse the parking lot facilities.

1. How many cars in the parking lot are over-crossing their own designated spaces into the one on the left side or one on the right-side space? If so, what is the percentage of all parked cars are crossing the lines of their own designated spaces?
2. What indication can you come with to show that those cars that were parked crossing into neighboring spaces might not be a random act?
3. Can you categorize into various group those identified cars that are over crossing their own designated spaces into the nearby space?

4. Do students feel it would be appropriate for citizens to write a letter to one of the following to bring to attention those cars which are not parking correctly on the designated spots (e.g., Figure 6)
    a. Supervisor and or manager of the parking lot facility.
    b. A police traffic officer.
    c. An elected official of the city or county where this parking lot is located.

Governance of Disability Parking Spaces

Parking lot facilities are governed by rules, codes, and polices that regulate their design, structure, operation, and use. For example, the minimum height from the floor to the lowest ceiling structure, such as a support beam, should be eight feet and two inches for areas providing access to handicap parking. Another example is that parking lots that have four or less spaces are not, by law, required to designate the accessible space with a sign. Why?

> *This means that for the purposes of local enforcement (at least in most jurisdictions), anyone, with or without a disability, can park in the accessible space. This is intended to excuse very small entities from having to reserve 25% to 100% of their available parking for individuals with disabilities. Residential facilities where parking spaces are assigned to specific dwelling units are also exempt from the requirement to post signs at accessible spaces.* [36, ¶. 19].

As shown in Appendix 1, a parking lot with 25 total spaces needs 1 accessible space. By the same token, a parking lot with 100 total spaces needs 4 accessible spaces, and a lot with 400 total spaces needs 8 accessible spaces, and two of these 8 must be designated as van-accessible. However, accessible spaces "must connect to the shortest possible accessible route to the accessible building entrance or facility they serve" [36, ¶. 6]. Students could research their own state and local laws to see if there are additional requirements or regulations on the designation of parking availability for individuals with disabilities.

1. Does this identified parking lot facility have specific designated area or spaces for individuals with disabilities? If yes, what is the total percentage of this area and/or spaces in comparison to the total area or the space in the parking lot?
2. Are there cars that are incorrectly parked in spaces designated for individuals with disabilities?
3. Do students feel about it would be appropriate for citizens to write a letter to one of the following to bring to attention those cars which are not parking correctly on the designated spots
    a. National Association for Individuals with Disabilities.
    b. Supervisor and or manager of the parking lot facility.
    c. A police traffic officer.
4. What have you learned from engaging in this exercise?
5. If you have to re-redesign or re-do this activity all over again, how would you do it and why?

Making the Connection to Other Disciplines

Collaborate with teachers who teach social studies by allowing students to use their collected data and information as starting point to explore and learn about civic engagement and social responsibilities in their surrounding community. Unlike *civic* duty that everyone is legally obligated to do as requirement of being citizens, civic responsibility involves actions that are not mandated by law but are beneficial to society and contribute to the common good. Civic responsibility, as defined by *Dictionary.com* is *the* "responsibility of a citizen," comprised of actions and attitudes associated with democratic governance and social participation. Citizenship means "a productive, responsible, caring and contributing member of society" ([37], [38]). This meaning is best reflected in the following definition of "academic service learning: "Service-learning programs involve students in organized community service that addresses local needs while developing their academic skills, sense of civic responsibility, and commitment to the community" [39, ¶. 3].

VI - Alternatives and Variations – Further Growth

Beyond the local parking lot, students can consider the structural issues of buildings, US car industry, global manufacturing of cars, design of cars, general design of buildings, and decisions faced by parking lot owners.

1. Parking Lots and the Weight of Car Loads

How do civil engineers know whether their design structure for a given parking lot is capable or not to resist the given car loads?

It is not unusual to encounter some people who, for a number of reasons, don't like to park their cars in parking lot with more than one floor. One of these reasons is that they don't trust the structural strength of the parking lot to hold all these cars in the upper floors. However, the wonder of "how do parking garages hold the weight of all those cars in multiple levels" was raised by almost all the students who participated in parking lot learning activities. Furthermore, this question has also been in interest of many adult people. For example, *"How do parking garages hold the weight of all those cars, especially on the lower levels when the weight of all the cars above is cumulative?"* has appeared in Quora Website [40] with many respondents from professional civic engineers and articular designers, to name a few. (See Appendix 3 for weights)

In this learning activity students are individually challenged to conduct research and to look for and interview an engineer to find out

1. What do civil engineers do to ensure their designed structure for a given parking lot is capable of supporting the given car loads?
2. How do civil engineers know whether their designed structure for a given parking lot is capable of supporting the given car loads?

However, teachers also need to know or have an idea about this concept before assigning this activity to their students. For example, Bruce Feldman, a real estate consultant and broker in New York, clarifies that "The parking structure does not hold the weight of the cars, nor is the weight "cumulative" to the lower levels; all the weight of every level is transferred to the ground through the structural columns." Another response to the question in Quora Website pointed out that "parking lot loads are not very heavy. Cars are heavy, but they occupy large areas. This means their weight per square foot is quite reasonable and not as great as even some people load types." While, Ciaran Mahood, a civil engineer on construction sites for more than 20 years in 6 countries, simplify the concept by saying that:

> *In simple terms each floor slab "brings" the load to the beams and columns. The columns "bring" the load directly from any floor slab to the foundations so for example the top floor has no effect on the floor below. All the load from the top floors is "brought to the foundations. Repeat for each floor. This is how 100 story buildings work. Only the columns (and core) bring the vertical loads to the foundations.* [40]

This means that the civic and architecture engineers designed their desired structure's columns and floors in a way to support the expected weight using steel reinforced with concrete. In doing so, they used a lot of math and conclusions to reach the desirable design, amount of steel and concrete needed, as well as in how to construct the building step-by-step.

2. Globalization, Car Distribution, Industry, and Manufacturing

Cars are the transportation mode in all countries with no exception. While there are countries without trains and some without a major international airport, no country today is without cars, yet only a few countries in this world really manufacture cars and car related products and parts. Those countries which manufacture cars also have in their streets, roods, and highways as well as cars that are made in other countries.

In this learning activity, students are asked to conduct research to find out:

1. How many different countries are there in the world (countries that are recognized by the United Nation)?
2. Which countries do manufacture cars?
3. What is the percentage of the countries that manufacture cars in the world?
4. What was the first country to manufacture a car?
5. What was the first country to manufacture cars in large-scale commercial use?
6. What was the latest country to enter the country club of manufacturing cars?
7. Which country manufactures the most number of cars?
8. Which country manufactures the most number of different types of cars?
9. Which country manufacture the most environmentally friendly car in the world?

10. Which country manufacture electrical car(s)?
11. Which country manufacture self-driven car(s)?
12. Which country manufacture the largest (biggest) car in the world?
13. Which country manufacture the smallest car in the world?
14. Which passenger car is the most expensive one in the world? Which country manufactures this car?
15. Which passenger car is the most inexpensive one in the world? Which country manufactures this car?
16. What are the five leading countries in rubber production in the world?
17. What are the five leading countries in oil and petroleum production in the world?
18. What are the leading countries in tire manufacturing and production in the world?
19. Which country is manufacturing your favorite car?
20. Should small cars and electrical cars treated different than bigger and gasoline cars? (Figure 7)
21. What surprised you the most encounter in conducting this research and for answering these questions?
22. What have you learned from answering these questions?

After answering these questions, answers should be put in a written assay format for publication in a local newspaper directed to educating the local community about these findings.

Figure 7
Should small cars and electrical cars treated different than bigger and gasoline cars?

<u>Dissuasion Question:</u>
- Should parking fees in streets and parking lots be determined by car size?
- Should fee structures for street parking and parking lots of electrical cars be less than cars that use gasoline?

<u>Making the Connection to Other Disciplines:</u>
Collaborate with teachers who teach English language and writing by allowing students to use their collected data and information in their writing and compositions course assignments. Students can also use their collected data and information in their geography, economic, etc. classes to discuss the role of globalization in the development of the modern world. Students can also discuss that in today's interdepend world, could a given community, society, and or country offered to live, survive, and sustain its existence in isolation from others!

3. Designing Cars

a. Designing Dream Cars

The objective of engaging students in this warm-up learning activity is to prepare students' mindsets to be ready to engage in learning mathematics by discovering and generating data and information through observation and exploring cars in school or a near-by parking lot facility. The following warm-up activity is designed to ensure students are motivated and ready to engage in learning mathematics and applying what they learn in various situations.

To start with, ask each student to answer the following:

1. Identify your favorite car, make a sketch of it on a piece of paper, and then write down why you select this particular car as your favorite one; including the unique features that distinguishes it from other cars including weight, length, width and size, powered by electrical or gasoline engine, etc.? Let the students know that they are free to use their realistic and informative imagination.
2. Allow students to talk and share their selection with their classmates in the classroom.
3. As a homework assignment, ask each student to conduct research about their selected favorite car, and create a portfolio that she/he can use to convince others that this car is worth buying, having, and keeping.
4. Each student should write at least one page to summarize his/her final outcomes and what they have learned from answering these questions.

In the next class meeting, and based on the class-time availability, randomly allow some students to openly share their summary with the rest of the class and start an open discussion, perhaps as a warm up to the following learning activity. Some students become attached emotionally to their favorite car, which can fuel even more productive discussions going forward.

b. Designing the Future Car

As professor Ben-Joseph (2012) from the urban planning at M.I.T., when it comes to cars, our current society is an automobile-oriental society. With this in mind and the fact that the future is always influenced by what current students, the future generation, can do and achieved at all levels to make and take the society forward, and future cars are only one of many that most likely will look different in the coming future not only how they would be powered (fossil fuel, solar energy and or hydrogen) but also how they look, drive, and operate. The following activity is design with this goal in mind.

1. Divide the class into groups of 3-4 students.
2. Name each group as a design unit or unit of design, with a general manager and associate members of engineering.
3. Assign each group one of the following units of design: Wheels and associate unit design, Engine unit design, Body work and shape unit design, Size and weight unit design, Color and light unit design, Engine, speed, and velocity unit design.
4. Ask the members of each team to work together starting by brainstorming on how they are going to work and design their designated task and responsibility. Give the groups enough time to complete this task.
5. When all the groups have agreed upon plan for their designated design and how they are going to accomplish them, bring the groups together and ask each team members to present their design and the reason behind it. The members of all the other groups can ask questions and challenge the presenters about their design if they choice to do so.
6. Remind the members of each group that they must take in consideration the points and the concerns that the members of the other groups raised about their design of designated part of the car.
7. Give the members of each group one week to work together and to finalize their design of the designated part of the car both in drawing and writing and submit to the teacher. Upon receiving the arrival from the teacher of the class, each members of each group must again present their final product in the class.
8. Finally, each group will select a member to represent the group in integrating all the designs of various part of the care in one comprehensive design. Upon completion. The group present their design to the whole class.

<u>Making the Connection to Other Disciplines:</u>

Collaborate with teachers who teach physics, chemistry, engineering, and or design by allowing students to use their collected data and information as starting point to explore and learn about how, for example iron, oar, aluminum, copper, zinc, silicon, and rubber to name a few are extracted and which are the leading producing countries of these substances in this world. From there teachers could explain how most types of matter exist as compounds (a matter that made up of two or more different kinds of atoms linked together). They can also talk about why there are fewer elements (a matter made up of only one kind of atom) than there are compounds in this world. They can talk about and differentiate between metals and non-metals, etc. From there, teachers could start teaching about various concepts and topics in chemistry and related subjects such as chemical reactions, metal activity, corrosion, hard water, the important of metals to life and health, etc.

4. Designing and Building a Strong and Lasting Parking Lot

Designing and building a strong and lasting building is the dream of every civic engineer as well as those who own a given building, and car parking lots are no exception. In this learning activity, students survey and investigate given parking lots and identify whether or not they are strong enough based on the geometric shapes of their support columns that are used to hold and support the floors and ceilings.

1. Identify parking lots nearby your school that have more than one floor.
2. Divide the students into groups of 2-3 to work together as a team, and assign them a given parking lot. If possible, assigned groups of students to different parking lots. If not possible, assigned students to work in different floors of a given parking lot.
3. Ask the members of each group to visit their designated parking lot and to:
    a. Draw sketch of its floors, entrances, exits, etc.
    b. Identify the number, location, and the type of all the support columns that are used to hold and support the ceiling of each level of their designated parking lot. The types of support columns could be rectangular, solid prism, circular solid cylinder, hexagonal solid prism, cube solid prism, square pyramid prism, etc.
    c. Create data table to organize their gathered data and information. In addition, the members of a given group could also present their data in charts or graphs.
4. Upon completion, each group of students must submit their final report to their teachers and present their findings in the class.

In the class, the teacher would work with the students to:

1. Put all the data and information collected by students into one data table.
2. Add all of the data collected from parking lots related to the locations, the types, and the number of support columns that hold the ceilings such as rectangular solid prism, circular solid cylinder, hexagonal solid prism, cube solid prism, square pyramid prism, etc.
3. Divide the total numbers by the number of parking lots students visited to get the average number of each type of floor-support columns.
4. Identify which of the following support columns are the most common and which are not common on each parking lot: rectangular solid prism, circular solid cylinder, hexagonal solid prism, cube solid prism, square pyramid prism, etc.
5. Explain why those that are the most common are used the most, and those which are the least or not used as all, are less common in the construction of parking lots.
6. Infer if the explanations in response to question 5 could also be applied to most other types of buildings.
7. Then challenge the members of each group to:
    - Calculate the area and the volume (mass) of the 3D-bases of the support columns that have been identified; for example: rectangular solid prism, circular solid cylinder, hexagonal solid prism, cube solid prism, square pyramid prism, etc. (Table 4)
8. How the circular cylinder floor-support columns are the most common ones; and what make them stronger than any other 3-D solid shapes (e.g., Figure 8).
9. Table 3 is example of what students found in one visit to nearby 10 parking lots in a city in a metropolitan area in the Midwest of the United States.

Table 3
Various Types of Support Columns Usually Seen In Parking Lots

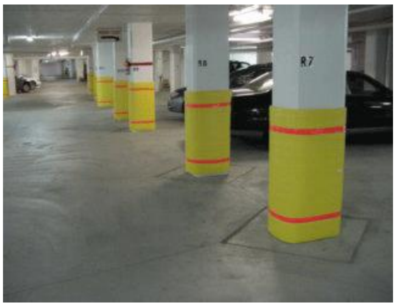
Support Columns	Number of Columns
Circular solid cylinder	68
Cube solid prism	42
Rectangular solid prism	16
Hexagonal solid prism	12
Pyramid prism	0

It is important for students to learn how to calculate the area and the volume as well as what make the shapes different from each other. Students can also discover why civil engineering and construction industries prefer to use more circular solid cylinder bases in buildings and parking lots than the other types of columns solid shapes.

Making the Connection: Parking Lots and Scientific Method of Investigation

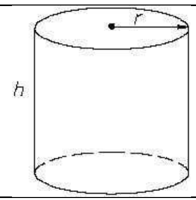
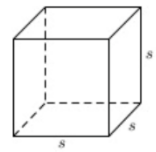
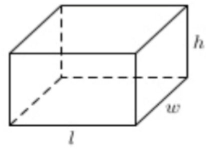
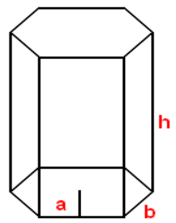
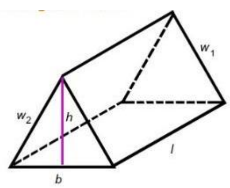
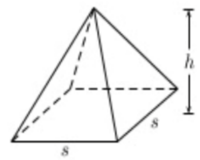
It has been reported that car drivers leaving a public parking space often have a tendency to be territorial "even when such behavior is contrary to their goal of leaving the parking space." In other words, when drivers see other car waiting for their parking spots, it take them longer to leave their spots than when no one is waiting for their spots. Do drivers really take longer leaving a parking spot when others are waiting for it? Ask your students to consider if it is possible to design and conduct scientific experiments to investigate whether or not this claim can be scientifically verified. If not, what are the mitigating factors that could impact this experiment? When you students successfully complete their scientific investigation, and discuss in the classroom, provide them with an access to Alexis C. Madrigal's article titled "Science: People Really Do Take Longer Leaving a Parking Spot When You're Waiting For It", which published in *The Atlantic* on Feb. 18, 2011.

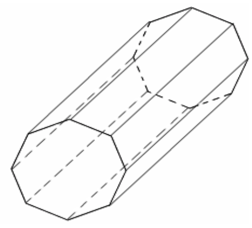
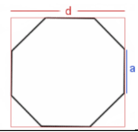
Figure 8
Four Different Types of Support Columns in Various Parking Lots



https://www.google.com/search?q=floor-support+columns+in+parking+lots&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwibyM-X__3YAhXqSN8KHVMUDMUQsAQILg&biw=1366&bih=634

Table 4
Surface Areas and the Volume of Some 3-D Solid Objects

3D-solid objects			Calculating the surface areas and the volume (mass) of the 3D-solid objects	
		Surface Areas (SA)	Volume (mass) (V)	
Circular Solid Cylinder	h: height of the cylinder r : radius of the base	$2\pi r^2 + 2\pi r h$	$\pi r^2 h$	
Cube Solid Prism (Cube)	s : edge length of the cube	$6s^2$	s^3	
Rectangular Solid Prism	l : length w: width h: height of the rectangular prism	$2(l h + lw + wh)$	$l h w$	
Hexagonal Solid Prism	b: base length of the hexagonal prism a: apothem length h: height of prism	$6b(a+h)$	$3ab h$	
Triangular Solid Prism	w_1, b, w_2: sides of the bases of the prism h: height of the triangular base l : length between triangles	$b h + (w_1 + w_2 + b)$	$\frac{1}{2} b h l$	
Square Solid Pyramid	s : side length of the square base of the square pyramid h: height of square pyramid	$s(s + \sqrt{s^2 + 4h^2})$	$\frac{1}{3} s^2 h$	

Octagonal Solid Prism	A: area of base of the octagonal prism a: side length of base l: length of octagonal prism d: span of the octagonal base	2A + 8al	2adl	 

5. Designing and Building a Strong and Lasting Building

In this activity, the students are challenged to verify their conclusion from previous activity (Building a Strong and Lasting Parking Lot) by investigating buildings around their school.

Divide the students into groups of three students and ask each group to see whether or not the data, information, inferences, and conclusions they reached in previous activity can be also seen in nearby buildings. In other words, challenge each group to verify their conclusions by investigating nearby existing buildings to identify which of the following floor-supporting columns are the most common and which are not common on each explored building: rectangular solid prism, circular solid cylinder, hexagonal solid prism, cube solid prism, square pyramid prism, etc. In the case of buildings under construction, ask students to look for the main engineer(s) and or the manager responsible of the building to ask him/her if they are using more of the specific floor-supporting columns and not the others in the building. Finally, ask the students to write a report that is intended to be shared with the community and publish in a local newspaper.

6. Which Design Is Best for My Customer and Business?

As industrial design professor Rajib Adhikary, formerly of the Indiana Institute of Technology, and now the founder of KAALO Experience Design, explained design is nothing but finding a solution for a problem or a need and as such in design form follows function. Furthermore, while Mother Nature is the greatest industrial designer in any sense of the word, every human being is a designer because of this design is the oldest profession of mankind (cited in [34], [35]). With this in mind, the through the following learning activity, students are provided the opportunity to engage in designing a parking lot.

Divide students into groups of three students. Then give each group a copy of the following scenario to read on their own and consider. In the class, read the scenario to the whole class, and give the groups one or two weeks to create the best design for that scenario. Students should be able to justify their proposed design to the owner by addressing the needs of customers and the business.

Scenario:

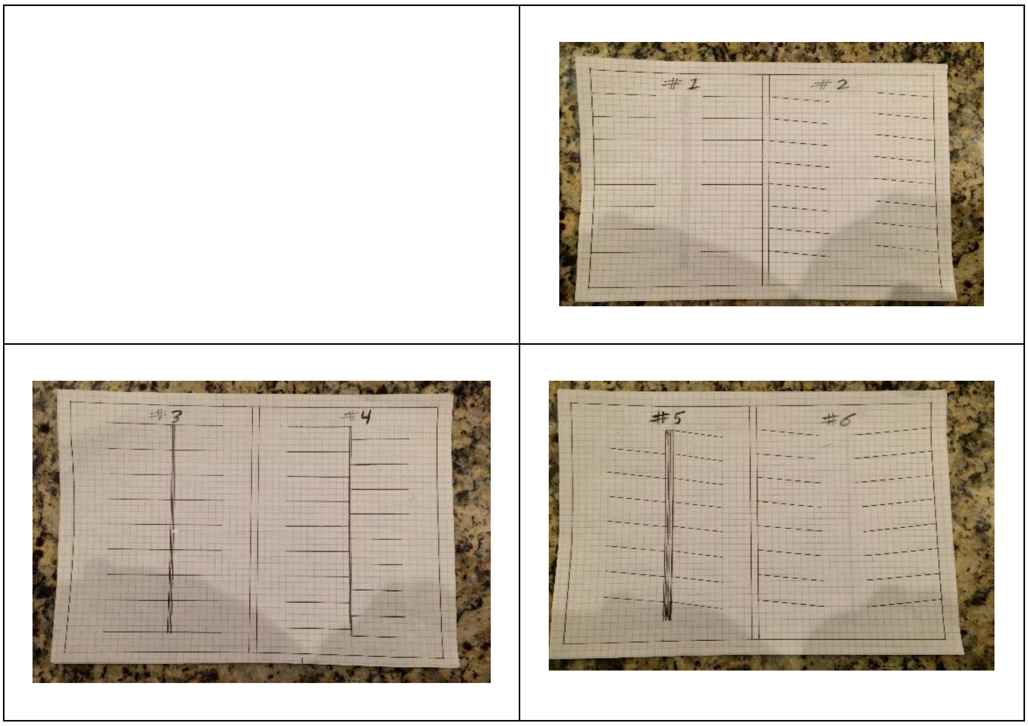
You are a very well-known consultant specializing in urban environmental design for both commercial and residential construction. You have been approached by owners of a new store in your area and asked to design a parking lot for the store that is:

1. Accessible to all
2. Customer-Friendly
3. Age-Friendly
4. Safe with low risk of automobile and predations accidents.
5. Maximizes utilization of the space for as many potential cars as possible.
6. Meets the zoning and parking local and city codes.

The store occupies one whole block that is extended between two roads. Therefore, the store has only one parking lot located in front of the store. The area in the back of the store is an alley devoted to loading and unloading only.

The owners of the store have given you three different proposals for designing their parking lot as a starting point (e.g., Figure 9). It is up to you and your team to either select one of them or come up with your own design. The most important element is that you justify to the owners which design is best for them, why it is best, and also why the other designs are less ideal.

Figure 9
Proposals for Parking Lots



Architectural Technology and Architectural Design

Engineering is the science of designing and applying solutions to existing and/or anticipated problems based on solid knowledge of science, mathematics and technology. So often however, unlike mathematical knowledge, the specific knowledge of science and/or technology that is needed is not presented to the engineers working on a given problem and thus it must be figured out, discovered and/or invented before applying to solve a given problem.

Students in upper class levels, can be challenged to provide architectural design and re-design of existing parking lot facility. To do so, they need architectural and engineering drawings such as floor plans, elevations, sections, and perspective drawings. They fill in the details of building drawings and specifications using what they have learned from the gathered data and information. Later on, they need to follow their sketches, specifications, and calculations to prepare more detailed drawings and to construct solid models.

As designers, students need to first:

1. Make 2D sketches of the targeted parking lot, submit to their teacher and obtain approval for the proposed designed.
2. Transfer their 2D sketch into 3D design and 3D CAD using construction materials, and computer software for pictorial rendering of buildings.

The reason that students are asked to engage in designing a parking lot is to give them the opportunity to apply what they learned in practical form. In addition, design has a lasting pedagogical impact on students simply because it fosters thinking, then imagination, and creativity, and finally innovation ([34], [35]).

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VII - Using Roads Rather Than Parking Lots

As Ben-Joseph (2012) wrote, in the U.S.A. for example:

> *It's estimated that there are three nonresidential parking spaces for every car in the United States. That adds up to almost 800 million parking spaces, covering about 4,360 square miles — an area larger than Puerto Rico. In some cities, like Orlando and Los Angeles, parking lots are estimated to cover at least one-third of the land area, making them one of the most salient landscape features of the built world*. [31, ¶. 3]

But what if sometimes there are no school parking lot facilities nor a convenient one nearby. In this case, teachers can find alternatives and modify the learning activities to achieve the stated objectives and outcome. The following is an example of a modification during a very rainy week when students would not be able to go outside.

Students would go to an upper floor of the school, into a hallway which has windows to the outside of the school where cars can be seen going in two directions. Ideally, the road would be a 4-lane road with 2-lanes in each direction.

Students would work in groups of three, with two groups assigned to collect the same type of data. Data could be collected on the color of cars, the size of cars, the type of cars, the number of the cars pass the school from left to right, and the number of cars passing the school from right to left.

Then, for each pair of groups, one group would be positioned at one end of the hallway, and the other group at the other end of the hallway. The groups would record their observations at for one hour. Data collection would be repeated for 4 days for the same hour each day.

After four periods of observations, some student may be concerned that their data and information might not be good enough because they don't represent the whole picture about the traffic passing by the school and or the type of cars in the neighborhood and the community. In other words, the cars of that one hour might not be a good representation of the traffic passing by the school.

To address this concern, data could be collected at different times of the day. This would like require permission of the principal of the school as well as colleagues who taught a similar group of students at different times during the day. A plan could be worked out that would allow students to record observations during these times. For example, students could be allowed to collect data and information at 9:00 AM and at 3:00 PM but only twice a week at each period of time instead of four times a week (e.g., Table 5).

Then, Ackoff (1989) techniques could be used to help students organize their data, create meaningful information, and build knowledge. Throughout this work, it would be very important for students to understand the differences between data, information, and knowledge as well as how data can be transformed into information, then into knowledge.

Table 5
Periods and Times of Observation and Data Collection

	11:00 – 12:00 Noon	9:00 – 10:00 AM	3:00 – 4:00 PM
	Four classes period of observations	Two classes period of observations	Two classes period of observations

<u>Making Connections: Efficient Use of Space</u>

According to the mathematician Professor David Percy of Salford University, most parking lots have inefficient design when it comes to how their parking space lines, or bays, are often set at 90-degree angles compared with the travel lane. As professor Percy has explained, "[T]his system is quite inefficient in terms of use of space because the lane between the bays needs to be wide enough to allow a car to reverse out its entire length before driving away." [41, ¶., 3].

Professor's Percy's solution to this inefficient persistent problem is very cheap and simple. Re-measure and re-paint the parking space lines setting them at 45-degree angles, rather than 90 degrees. With this change, the travel lanes can be narrower, allowing for a 23 percent increase in space. In a typical 500 space lot, that could add 119 parking spaces, increasing revenues and profits. It's possible that 36-degree angles might be even more efficient, but harder to measure. [41, ¶., 5].

Teachers could use Professor Percy's observation and recommended solution as a learning experience. Students could use measuring tapes and cameras to go to various parking lots around the school and their own communities, to investigate Professor Percy's observation.

1. Students would physically measure at least 10-15 parking spaces, randomly, in a given parking lot.
2. They would take photos of a number of spaces and lanes in a given parking lot.
3. When all the students complete their tasks, start open discussion on the veracity of Professor Percy's observation and solution.
4. Finally, ask students to design alternative line configurations for parking lots and determine if those ideas increase the efficient use of space.

VIII - Evaluation and Assessment

When thinking about assessment in these types of learning activities, instructors need to keep four important facts in mind. First, experiential learning is built upon the foundation of inter-disciplinary, multi-disciplinary, and a constructivist approach [11]. Second, "the means are as important as the ends" ([42], [43]). Throughout the activity and assessments, students should be provided with in-depth and frequent feedback. In this way, students can take charge of their own learning. Third, keeping the assessment method student-centered as much as possible. Fourth, using multiple assessment approaches that extend to all aspects of the learning environment, learning means, learning process, and learning outcomes in assessing student's understanding and success.

Using a pedagogical approach such as the one implemented in this set of activities, a broader and deeper meaning of assessment is needed that uses a multiple measurers to determine what matters most in student's learning and success. With this in mind, authentic performance-based measurements of student learning are considered the most appropriate with this set of activities. Specifically, assessments should not only measure students' grasp of basic skills and factual knowledge, but also integrate multiple complex capabilities like conceptual understanding, and long-term transfer of skills such as analysis, critical thinking, problem solving, and other higher-order skills.

Performing measurements such as these can be achieved by providing students the learning opportunities to become assessment capable learners. For example, students could be asked "what have you learned from actively engaging in a given activity", and "if you could re-design and or re-do it, how would you do it and why". Through these types of questions, they are able to think, reason, and apply what they acquired content knowledge to answer questions, solve problems, and explain new and different phenomenon. In other words, they become assessment capable learners through performance and demonstration. Throughout the process of asking students to apply their learning and explain their reasoning, they should demonstrate evidence of mastering endeavors through individual and group engagements and efforts.

1. The post-activity discussion:

The post-activity discussion is very important for students' cognitive and social development because it encourages understanding of the social and personal dynamics involved in collaboration for reaching informative inference and conclusion that not only reflect the shared understanding among, for example, the members of a given group, but also how students communicate and interact with each other during the exploration, inquiries, and the learning process ([44], [45]). The teacher and students should explore how and why each group reached its decision, and whether this situation could have been approached in other ways [46].

2. A written paper

A written paper in which each student could reflect by answering the questions of "What have I learned?", "How can I apply what I have just learned?", and "If I had to re-design and or re-do it all over again, how would I do it and why?" are important questions in helping students translate numbers into written form which is needed for the students to:

a. Demonstrate their understanding of learned concept and skills.
b. Demonstrate communication skills.
c. Understand that math is both knowledge and language, as well as tool for discovering meaning and understanding.
d. Understand that math (i.e., numeric, algebraic skills, etc.) has very useful applications.
e. Help students make the connection between concepts, skills, and application within the realm of mathematics and real life.

3. Student's level of cognitive involvement

Monitoring and recording the level of cognitive involvement of the members of each given group during conducting individual activities, as well as their involvement and discussion of learning activities have been used as successful assessment tool in helping teachers evaluate their students and help them learn. For example, using Table 6, teachers can record the type of questions being asked by students (individually and in groups) as well as the relevancy of the questions to the subject matter and to the point being addressed. In addition, teachers can use Table 7 to record the type of questions or conditional statements and their values for assessment purposes.

Table 6
Individual group questions analysis and account.
Adopted from Cherif, et.al ([47] p. 350)

	Type of Question or Conditional Statements	Extremely Relevant	Relevant	Less Relevant	Not Relevant	Total of Questions	Additional Observation
1.	Why						
2.	How						
3.	What do you think if...?						
4.	Which						
5.	What						
6.	When						
7.	Where						
8.	Is/Are						
Total of questions and or wondering statements							
Source: [47].							

Table 7
Type of Questions or conditional statements and their values for assessment purposes
(Adopted from Cherif, Movahedzadeh, Michel, Aron, and Jedlicka, 2011, p.20)

Type of Question		Why How	What do you think if	Which	What, Where, When	Is Are	Total
Extremely Relevant	# of Questions						
	Value per question	5	4	3	2	1	
	Total Values						
Relevant	# of Questions						
	Value per question	4	3	2	1	0.5	
	Total Values						
Less Relevant	# of Questions						
	Value per question	3	2	1	0.5	0	
	Total Values						
Not Relevant	# of Questions						
	Value per question	1	1	0.5	0	0	
	Total Values						
Total							
Source: [48].							

4. End of Session Discussion Questions:

- Based on the data collected and the interpretation you have made, can you make an informed prediction on the type of people who are using this parking lot to park their cars? Why or why not?
- What is the most convincing sound argument that you might use to the city in which you live for requiring all the parking lots in the city use more than one source of generating energy and electricity to power the lot?
- What is the most convincing sound argument that you might use to the city in which you live for requiring the use of "Size-Based-Pay" for customers to park their cars in paid-parking lots? Meaning there is different fee for different car sizes.
- How do you convince and demonstrate to a number of doubters that mathematics is "language", "tool", and "knowledge"?
- Some parking lot with multiple floors have only one type of support columns, while some others have more than one type of support columns either in the same floor level or in different floor levels. What type of explanation that you might come with to explain why and how?

In short, throughout the learning process, students are asked to explore, inquire, and build knowledge through experience and application. For assessment to be effective, it must measure what matters the most in helping student learn and succeed ([49], [50]). The activities described here strive to show students that mathematics is a tool, language, knowledge that can be used to enhance problem solving abilities and analytical focus. Assessments look for evidence of development and progress in students understanding, as well as their abilities to apply what they have learned in various situations. For example, measuring and calculating the surface area and volume of each supported column in a given parking lot and then make a comparative analysis between various types of supported columns in the same given parking lot demonstrate that the students gained the needed skills and acquired the essential knowledge needed to be able to make inference and conclusion about, for example, which type of supporting columns are best for a given parking lot.

IX - Conclusion

In his article "When a Parking Lot Is So Much More", Eran Ben-Joseph (2012) wrote that:

> *I believe that the modern surface parking lot is ripe for transformation. Few of us spend much time thinking about parking beyond availability and convenience. But parking lots are, in fact, much more than spots to temporarily store cars: they are public spaces that have major impacts on the design of our cities and suburbs, on the natural environment and on the rhythms of daily life. We need to redefine what we mean by "parking lot" to include something that not only allows a driver to park his [or her] car, but also offers a variety of other public uses, mitigates its effect on the environment and gives greater consideration to aesthetics and architectural context.* [31, ¶. 2]

With this in mind, these learning activities were designed around parking lots as sites for collecting valuable data and information. More importantly, these data then generate valuable knowledge, wisdom, and critical thinking, solidifying students' enthusiasm for and understanding of math and other STEM concepts.

Experiential learning theory brings light to teaching pedagogies that promote active learning with real world implications. Each of these parking lot activities provides students the opportunity to learn through direct data collection and analysis. Coming out of the classroom allows students the freedom to incorporate critical thinking in daily living adventures.

Parking lots are a common structure in daily life that reveal space, weight, design, selection, and governmental regulations all in one place. These activities not only provide students the opportunity to experience the essence of mathematics at work, they become aware of the role mathematics has played in creating and designing even such a relatively simple structure.

The growth opportunities through these exercises provide an education at many levels of learning. From data observations to exercises of engineering, such real world activities bring students through Ackoff's (1989) pathway progressing from data to wisdom with confidence, appreciation and excitement for more STEM learning.

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XII - Appendices

Appendix 1

How Many Accessible Parking Spaces are Needed?
(ADA National Network, 2014, ¶.6)

Total Number of Parking Spaces in Parking Facility(Lot or Garage)	Minimum Number of Accessible Parking Spaces Required
1 - 25	1
26 - 50	2
51 - 75	3
76 - 100	4
101 - 150	5
151 - 200	6
201 - 300	7
301 - 400	8
401 - 500	9
501 - 1000	2% of total
1001 and over	20, plus 1 for each 100, or fraction thereof, over 1000
Source: [36].	

Appendix 2

Example of Lighting Requirement in Parking Lots
(Adapted from Dana Point Municipal Code, 2017)

Lighting in parking lots are done based on specific municipal codes and regulations established and enforced by legal authorities in cities where a given parking is located. This appendix below is one example.

	Areas	Required Lighting
1	Entrance and Exits	50 footcandles
2	Stairways	20-50 footcandles
3	Cashiering/Security Areas	20 footcandles
4	Travel Lanes and Ramps	10 footcandles
5	Elevators	10 footcandles
6	Parking Areas	3-5 footcandles
In addition, "blind corners must be provided with viewing mirrors maintained in a position and condition to provide adequate sight distance".		
Source: [51]. https://qcode.us/codes/danapoint/view.php?topic=9-9_35-9_35_120		

Appendix 3

Chart of Average Vehicle Curb Weight by Class

While it is not that hard to know the weight of a given car because the vehicle's manual or driver's side doorsill of every given car contains the weight of that car, most people have no idea how much the car they drive weigh, or why knowing this is an important for every car owner. It is true that almost all types of vehicles keep inching up and putting on more weight. Furthermore, while the "Vehicle weight can vary significantly by the type of car, the model, and even the year of the car or truck", it is not that hard to predict which car type and model on the average are heaver and lighter in weight. Table 8 shows example of the average weight of various classes of vehicles as reported in USA Today:

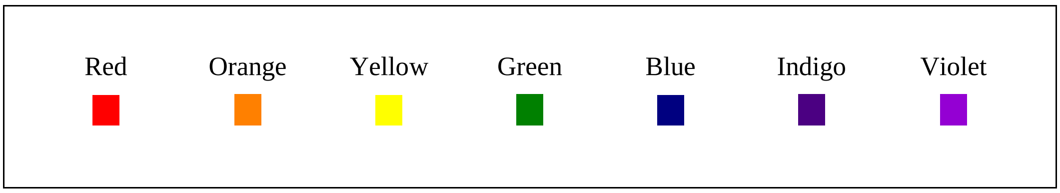
Table -8 - Car Weights

Vehicle Class	**Curb Weight in Pounds**	**Curb Weight in Kilograms**
Compact car	2,979 pounds	1,354 kilograms
Midsize car	3,497 pounds	1,590 kilograms
Large car	4,366 pounds	1,985 kilograms
Compact truck or SUV	3,470 pounds	1,577 kilograms
Midsize truck or SUV	4,259 pounds	1,936 kilograms
Large truck or SUV	5,411 pounds	2.460 kilograms
https://usatoday30.usatoday.com/money/autos/2007-07-15-little-big-cars_N.htm		
Discuss Question: Why should people pay attention to the weight of the car when they are shopping to buy a new car?		

Appendix - 4- Pigment vs Light Color

Today, cars come in different kind of colors, Rainbow colors as prime colors, and off-rainbow colors - various shaded of a given color. However, with the advance in technology, customers even can imagine a given color for their special order color of cars, and if they can pay the cost, they will get their imaginative designed colors. Fundamentally however, in 1671, Newton identifies five primary colors that were thought to be representative of how humans everywhere with normal vision see the rainbow. Later on, he added two more colors, culminating in what is now seven colors: red, orange, yellow, green, blue, indigo, and violet. Of course, a rainbow spans a continuous spectrum of colors – there are no "bands".

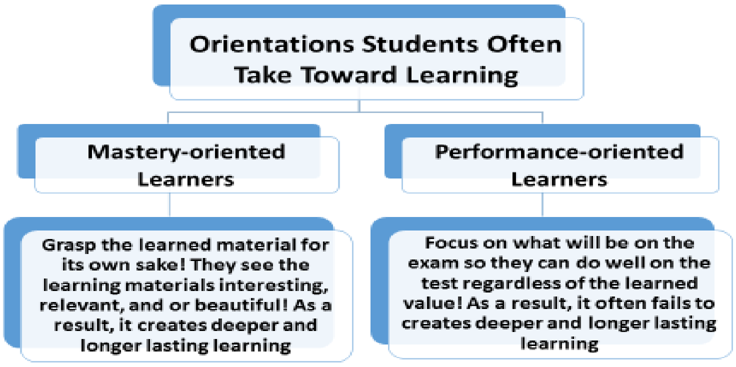
> *The apparent discreteness is an artifact of the photo pigments in the human eye and of the neural processing of our photoreceptor outputs in the brain. Because the peak response of human color receptors varies from person to person, different individuals will see slightly different colors, and persons with color blindness will see a smaller set of colors. However, the seven colors listed below are thought to be representative of how humans everywhere, with normal color vision, see the rainbow. (http://en.wikipedia.org/wiki/Rainbow , ¶. 1)*



http://en.wikipedia.org/wiki/Rainbow

Appendix -5 - Orientations Students Often Take Toward Learning by Lang (2016)

Orientations Students Often Take Toward Learning



Source: [52, p.7]

Appendix 6

Characteristics that Define an Activity or Method as Experiential
(Proposed by Chapman, McPhee, & Proudman, 1995, p. 243).

	Characteristics*	Meaning and Explanation*	Needed For**
1	Mixture of content and process:	There must be a balance between the experiential activities and the underlying content or theory.	Learning of key concepts through activities
2	Absence of excessive judgment:	The instructor must create a safe space for students to work through their own process of self-discovery.	Building confidence in one's ability to create their own learning
3	Engagement in purposeful endeavor:	In experiential learning, the learner is the self-teacher, therefore there must be "meaning for the student in the learning." The learning activities must be personally relevant to the student.	Stimulating ownership of learning
4	Encouraging the big perspective:	Experiential activities must allow the students to make connections between the learning they are doing and the world. Activities should build in students the ability see relationships in complex systems and find a way to work within them.	Developing real-world problem solving skills
5	The role of reflection:	Students should be able to reflect on their own learning, bringing "the theory to life" and gaining insight into themselves and their interactions with the world.	Encouraging critical thinking
6	Creating emotional investment	Students must be fully immersed in the experience, not merely doing what they feel is required of them. The "process needs to engage the learner to a point where what is being learned	Stimulating ownership of learning

		and experience strikes a critical, central chord within the learner."	
7	The re-examination of values:	By working within a space that has been made safe for self-exploration, students can begin to analyze and even alter their own values	Fostering personal growth
8	The presence of meaningful relationships:	One part of getting students to see their learning in the context of the whole world is to start by showing the relationships between "learner to self, learner to teacher, and learner to learning environment."	Supporting community involvement and collaboration
9	Learning outside one's perceived comfort zones:	"Learning is enhanced when students are given the opportunity to operate outside of their own perceived comfort zones." This doesn't refer just to physical environment, but also to the social environment. This could include, for instance, "being accounted for one's actions and owning the consequences"	Promoting responsibility and confidence
*Chapman, McPhee, & Proudman, (1995, p. 243). See also Schwartz (2012, p. 1-2).** By the authors of this paper.			

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