A Study on the Societal Attitudes Towards Terraforming Mars

Word Count: 5212

Introduction

Terraforming is the "...process of planetary engineering, specifically directed at enhancing the capacity of an extraterrestrial planetary environment to support life. The ultimate in terraforming would be to create an uncontained planetary biosphere emulating all the functions of the biosphere of the Earth–one that would be fully habitable for human beings" (Fogg, 1995a). This in turn would create a new home for mankind that would allow us to either expand our ever-growing human population or to take refuge in the event of a cataclysmic disaster that destroyed our Earth. However, despite interest in the idea of creating a new home, it has been discarded by many as an unachievable fantasy more than a possible reality. Is it truly possible to completely and utterly change the entire characteristics of a planet in order to make it compatible for mankind? Although it may not be financially feasible, at least not by one single nation, it is indeed believed to be possible and the process as a whole has been outlined by science fiction writers and planetary engineers alike for decades. As the research continues, environmental and planetary engineers interested in terraforming (simply dubbed "terraformers") continually revise potential outlines using real data and calculations to support the idea that terraforming is indeed possible.

However, there still remains a greater overarching problem that requires attention. Even if such a process was possible, what are teenage American societal attitudes towards terraforming another celestial body?

As of now, there exist no study that examines societal attitudes towards terraforming Mars, let alone terraforming another celestial body. The reasoning for this may be due to the fact that since terraforming another planet or celestial body does not appear to be happening anytime soon (we have yet to even send a man to Mars), there is no reason to see how the public feels towards such a process. However, insight on public opinion could prove to be valuable. If the

public responds favorably towards the idea of terraforming Mars, the federal government may invest more into studying the planet which would further help terraformers perfect their outlines or possibly commence initial discussions on terraforming another planet.

For the purpose of this paper, the planet Mars was chosen to find societal attitude towards terraforming. The reasoning behind this is that Mars is the most popular body that terraformers discuss when creating outlines so if a planet was to ever be terraformed, it would most likely be Mars (other somewhat popular celestial bodies are the planet Venus and our own Moon). As for the reasoning in measuring teenage American attitudes, if this research was ever expanded upon, the high school demographic is likely to be overlooked and not measured, therefore it is best that it is measured now while there is access to this demographic.

Literature Review[1]

Modeling Terraforming

For the most part, major terraformers agree with this basic outline (Ahrens, 2003):

- A temperature increase would lead to the melting of polar ice caps, thus releasing the trapped CO_2 and water
- At the same time, CO_2 and H_2O is released from the Mars regolith
- An atmosphere is created with water vapor, CO_2, and ozone, which traps the Sun's UV rays and further warms the planet
- Plants are introduced to begin ecopoiesis which leads to the beginning of O_2 and N_2 production and continues until it is suitable for human life

However, the hardest step to go through with is the very first step. How do we initiate a temperature increase on Mars that would lead to the melting of the polar ice caps? While there

[1] Underlined key words can be found in the Appendix for further clarification

are many proposals, the most popular is the runaway greenhouse effect which is what the procedure is slightly based on.

Ecopoiesis

According to Marty Fogg, 4 things are required in order successfully start ecopoiesis, "mean global surface temperature must be increased by ~ 60 K, the mass of the atmosphere must be increased, liquid water must be made available, and the surface UV and cosmic ray flux must be substantially reduced" (Fogg). However, in order to support plant life, Fogg states that "atmospheric composition must be altered to increase its O2 and N2 fractions" (Fogg, 1995b). There are various ways proposed in order to accomplish these requirements as shown in the following paragraphs.

Using the Runaway CO_2 Greenhouse Effect to Terraform Mars[2]

The runaway greenhouse effect, coined by Andrew Ingersoll who discovered the phenomenon while researching Venus, is the cycle in which a planet continually heats itself up due to the release of greenhouse gases into the atmosphere which leads to it to warm up more and so on and so forth (Ingersoll, 1969). An easy to visualize example he presents goes as follows: as Earth continues to heat up, a little bit of the ocean will evaporate into water vapor and go into the atmosphere which in turn causes more heat to be trapped and more water to evaporate and the cycle continues until the entire ocean evaporates (similar to what happened on Venus).
Why is this important? While not necessarily a complete solution for increasing the planet's temperature, it provides a somewhat self-sustaining method that would require the least amount

[2] The reason "CO_2" was added to the subheading instead simply being named "The Runaway Greenhouse Effect" is because, according to a study by J.B. Pollack, a NASA Ames researcher, there is convincing evidence that Mars once possessed a dense, carbon dioxide filled atmosphere and that is what terraformers hope to recreate (Pollack, 1987). [2] According to his calculations, it would take about 100 years to do so

of human interference. But how would this be initiated? Similarly, to the actual procedure presented earlier, there are a few variations on how this would be started, all requiring humans to "jump start" the process.

Originally, many ideas to terraform Mars began with Carl Sagan's (now obsolete) "Long Winter Model" which said that carbon dioxide was frozen away in the Martian ice caps (Sagan, Toon, & Gierasch, 1973). From this, Sagan writes in a follow up paper that greenhouse gases would need to be introduced in order to artificially reduce the albedo so that the ice would melt quicker[2] (Sagan, 1973).

However, with the discovery of the poles being mainly solid water with a thin layer of carbon dioxide, it is now believed that most of the carbon dioxide resides in the Martian regolith. This led Christopher McKay, a NASA Ames researcher, to study how to get the carbon dioxide out of the regolith. He found that an initial warming of 5-20K increases the atmospheric pressure enough to support a runaway that can remain in a stable end state of ~ 800 mbar and ~ 250 K (McKay, 1991).

Four major methods have been proposed that would in turn lead to the eventual thickening of the Martian atmosphere by releasing trapped carbon dioxide in the Martian ice caps and regolith. These next four methods, however, require an immense amount of human interference and are considered somewhat extreme. They are the "Space Mirror" method, the "Asteroid Collision" method, the "CFC Production" method, and the "Bosch Reaction" method[3].

a. Space Mirrors

The "space mirror" method was one of the first and most commonly proposed idea to heat up the surface temperature of Mars and the concept is quite easy to understand. Imagine

[3] These are not the actual names of the methods. They were dubbed in this way in order to quickly establish the main concepts behind each method. In reality, they are not named.

having a giant magnifying glass and concentrating the beam of light to burn something up, such as an ant or leaf. This is the basic principle of the space mirrors method. However, instead of ants and leaves, they would be pointed at the ice caps in order to melt them and start the runaway greenhouse effect naturally. According to Zubrin and McKay, "a 5 degree K temperature rise imposed at the pole should be sufficient to cause the evaporation of the CO2 reservoir in the south polar cap" through the use of a "space-based mirror" made of an "aluminized mylar material with a density of 4 tonnes/km^2" and radius 125 km (Zubrin & McKay, 1997). However, this is where the first problem presents itself. As of now, our modern-day rockets are not capable of sending something this massive to space. Zubrin and McKay thus propose crafting the mirror in space "out of asteroidal or Martian moon material" later down the line if spacebased manufacturing techniques ever become available (Zubrin & McKay, 1997).

b. Asteroid Collisions

Another major method to initiate the temperature increase is to send large ammonia-filled asteroids hurtling towards the planet. Why ammonia filled? Ammonia is a powerful greenhouse gas that could help with efforts to start a temperature increase. Zubrin and McKay then proposes the following: sending "an asteroid made of frozen ammonia with a mass of 10 billion tonnes orbiting the sun at a distance of 12 AU" to collide with Mars through the use of "a quartet of 5000 MW nuclear thermal rocket engines powered by either fission or fusion" as well as a gravity assist from Saturn, which would require "a DV of 0.3 km/s" (Zubrin & McKay, 1997). In simpler terms, they want to send a large ammonia-filled asteroid from the outer solar system on a collision course with Mars through the use powerful nuclear rockets and a gravity assist from Saturn. Why the outer solar system rather than the Main Asteroid Belt? According to Kepler's Third Law, the farther you are from the Sun, the longer it takes to complete an orbit around the Sun. This means two things: asteroids from the outer solar system move at a slower rate that

asteroids in the Main Belt and asteroids in the outer solar system require less of DV to change its orbit compared to those in the Main Belt. It would take approximately ten years of thrust followed with twenty years of coasting before impact. At impact, "the energy released would be about 10 TW-years[4], enough to melt 1 trillion tonnes of water" as well as "raise the planet's temperature by about 3 degrees centigrade and form a shield that would effectively mask the planet's surface from ultraviolet radiation" (Zubrin & McKay, 1997). Zubrin and McKay predict that about forty missions over a fifty-year period would be enough to start a natural runaway greenhouse effect. However, they admit that the feasibility of such a design is complicated due to the fact we have a lack of data on the ammonia-filled objects in the outer solar system.

c. CFCs

Another major method for warming Mars is through the production of CFCs in factories. Christopher McKay did a study on the use of CFCs and found that CFCs were capable of warming Mars up to 30K, but also noted that these CFCs lasted merely days or even hours instead of decades (McKay et al, 1991). This was due to the fact that, unlike Earth, Mars does not have an ozone layer to break UV radiation that shatters the bonds between carbon and chlorine. However, a study done by N. N. Ridder, D.C. Maan, and L. Summerer, researchers at the European Space Agency, found that artificial greenhouse gases, CF_4, C_2F_6, C_3F_8 and SF_6, would be able to raise the Martian surface temperature up .6K in a couple of years (Ridder, Maan, & Summerer, 2010). Given more time, these gases could be able to raise the surface temperature by about 30K. How do we transport or create these CFCs on Mars? According to Robert Zubrin's *Technological Requirements for Terraforming Mars,* these gases would be produced through a

[4] The energy output would be equivalent "to about 70,000 1 megaton hydrogen bombs" (Zubrin & McKay, 1997). While we could theoretically do this, it would be counterproductive due to the amount of radiation that would be introduced to the planet which would be incompatible with human life.

relatively straightforward process: create factories that are designed to cause global warming, or in other words, do what we are doing on Earth. These factories would require a lot of power[5] and a crew of several thousand for each. Given this much power and the size these factories would be, they could, in theory, produce enough CFCs to warm up Mars to start a greenhouse effect. More so, Zubrin and McKay say that after several decades, the atmospheric pressure of the planet would reach "tolerable levels" and the climate would become "warm and slightly moist" and the people working on the planet would be able to "travel freely in the open wearing ordinary clothes and a simple SCUBA type breathing gear" (Zubrin & McKay, 1997).

d. Bosch Reaction

Lastly, Dan Razvan Popoviciu, a Romanian professor at the University of Constanţa, suggest that the surface temperature be raised through a Bosch reaction. A Bosch reaction essentially calls for an atmosphere to be created using water vapor instead of carbon dioxide and other greenhouse gases (Popoviciu, 2010). However, the major problem with the method is a lack of hydrogen on Mars. There would need to be large amounts of hydrogen transferred to Mars in order to sustain the process. To have a sufficient amount of hydrogen, Popoviciu calls for the stellification of Jupiter and Saturn in order to both heat up Mars and have the resulting ejecta provide both hydrogen and to convert the resulting carbon into graphite to reduce planetary albedo (Popoviciu, 2010).

However, there is no way a guarantee that the stellification of the two planets would have this actual result. According to A.V. Turchin, a Russian transhumanist, states that there is the possibility that setting off a thermonuclear bomb could cause a destructive chain reaction that

[5] Depending on how much we want to raise the temperature, the amount of power required ranges from 1000-45000 MWe (Zubrin).

could lead the planet to blowing up (Turchin, 2010). At the same time, Popoviciu agrees it is highly likely that the process would produce a "fizzle" as in almost nothing would happen, or at least nothing big enough to matter (Popoviciu, 2010).

Despite the popularity of the runaway greenhouse effect, it is not without criticism. One of the most influential books on terraforming is Martyn Foggs' *Terraforming: Engineering Planetary Environments* which discusses the terraformation of not only Mars, but Earth and Venus as well. Here, Fogg examines the runaway greenhouse effect and criticizes it in being too problematic to control. And he is not wrong. It is important to note that this is exactly that is happening on Earth and, as of now, it is out of control. What is to say the same would not happen on Mars?

Rather than use any one method, Fogg synthesizes two of Zubrin's and McKay's methods plus his own ideas into one that would call for a smaller runaway greenhouse effect, greater insolation from "space mirrors", and nuclear mining to devolitize carbonates and nitrates (Fogg, 1995a).

Despite being written in 1995, it is still being used as a guide for terraforming today, as many are merely expanding on his initial ideas. In Peter Ahrens' *The Terraformation of Worlds*, Ahrens draws heavy influence from Foggs' initial ideas and applies more current data in his process to outline terraforming. For now, major terraformers will need to decide between which is better: a synergic approach that would essentially be dependent on human interference or a to go with the runaway greenhouse effect that could easily get out of hand and go wrong.

Methods

The purpose of this report is to answer the following question: what are teenage American societal attitudes towards terraforming Mars? In order to measure teenage American

attitudes towards terraforming, a study was performed on high school students attending a large suburban high school in California.

This school is a typical high school located in the ethnically diverse San Fernando Valley. In the 2016-2017 school year, the school contained 4,650 ethnically diverse students, with 39% Hispanic, 28% Asian, 26% White, 4% African American, <1% Native American or Alaska Native, and <1% Pacific Islander. Of these students, 52% (~2400 students) are socioeconomically disadvantaged. The reason for choosing this particular school as the target population is because they represent a typical suburban high school and this will allow for the conclusions found to be applicable to schools in a similar setting.

A professional sampling survey was designed to identify said attitudes. The reason a survey was chosen to identify these attitudes was to examine both how students feel towards terraforming Mars as well the extent to which these attitudes were expressed. The purpose of this survey was given to respondents before the survey was conducted so they were fully aware of what their answers were attempting to answer. A three-week deadline was given to respondents with the reason being the first 3 weeks of the semester are relatively lax and were able to provide ample time to complete a 10-minute survey.

With regards to the actual survey, the survey contained 15 questions, 6 of which were demographic and the rest that were created to measure societal attitudes towards terraforming. Of the remaining nine questions, four of the questions contained a Likert scale, three were yes/no questions, and two were free response questions. The survey was created using Google Forms, a tool by Google for the purpose of creating surveys or tests that collects data into a spreadsheet for further analysis.

The survey was loosely based off of a survey conducted by NBC News where participants were asked which areas did they want their tax dollars to go towards (Taintor,

2015)[6]. The survey included a similar question, with the notable inclusion of an option to terraform Mars. However, besides the tax dollar question from NBC, the remaining questions were originally created specifically for this survey. This was done because there is *no existing study* that could be applied to gather data on societal attitudes towards terraforming.

In terms of the sampling method, a stratified random sample was chosen for this survey. The population was divided into seven strata based on entrances to school and were dubbed accordingly: Hiawatha Entrance, "J Gate" Entrance, Kingsbury Entrance, "Flagpole" Entrance, Surface Road East Entrance, Surface Road West Entrance, and "Zelzah Parking Lot" Entrance (Table 1 shows the distributions of students by entrance and the actual responses collected following the data gathering phase for n=75). To ensure that the samples accurately represented the larger population, a random selection of subjects within each stratum were collected using a systematic approach. A student that walked through the entrance was greeted and asked to take the survey. Following this encounter, the next student that entered was skipped and the following student was greeted and asked to take the survey.

Table 1

Gate	Males	Females	Total	For n=75
Hiawatha	111	150	261	5
"J Gate"	85	44	129	2
Kingsbury	453	538	991	18
"Flagpole"	543	651	1194	21
Surface Road East	104	72	176	4

[6] As stated earlier, *there exist no study on societal attitudes towards terraforming*, so the inclusion of parts from this survey serve only to give some validity to the questions asked.

Surface Road West	242	254	496	8
Zelzah Parking	505	450	955	17
Total	2043	2159	4202	75

Data was collected through the use of aforementioned Google Forms. The subjects were aware of the data collection process, but were kept anonymous, in order to compensate for a possible social desirability bias. The survey was distributed electronically to the students' school-created emails as soon as they agreed to take it and was due February 3rd. All responses were stored on Google Drive in a designated folder label
"Survey Responses" and were later be analyzed in Microsoft Excel.

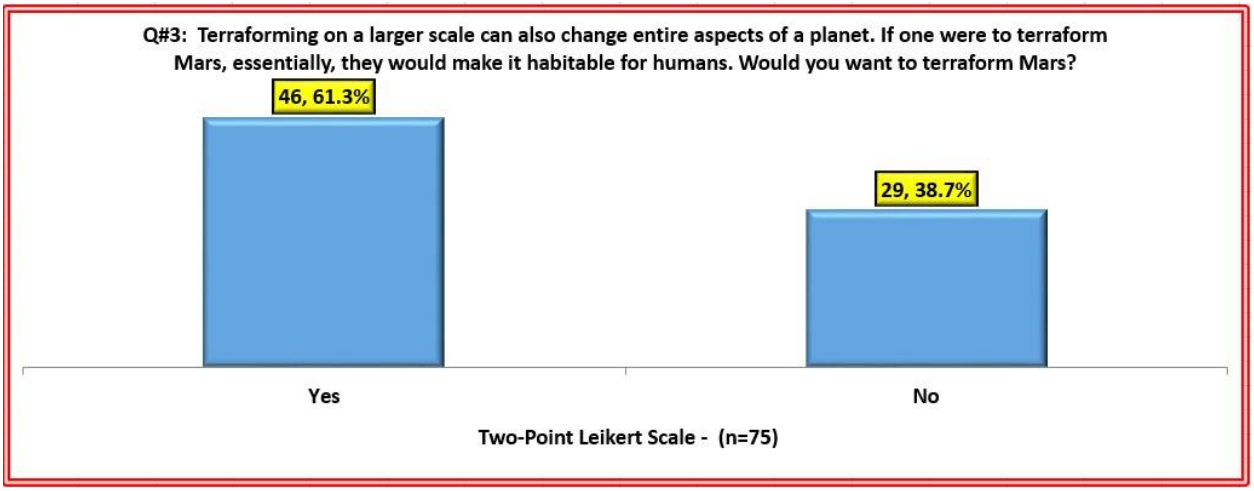
At the conclusion of the data gathering phase, a sample size of 75 was chosen from the data. In the event of an excess amount of data for any one stratum, data was randomly discarded in order to keep the proportions similar to the ones found in Table 1. After the final sample size of 75 was chosen, descriptive statistics were used to explore and explain the general trends found in the data and interpret what the data said about the previously mentioned attitudes. Unfortunately, inference procedures, including estimates of population proportions using confidence intervals and one-sample tests of significance, could not be used since the data could not be compared to an existing parameter (said parameter is believed to not exist). To make sure the conclusions drawn from the sample were an accurate reflection of the population, the top bias identified, social desirability bias, have been compensated for through the reinforcement of anonymity of responses. The reinforcement of their anonymity hopefully enticed respondents to answer the survey more truthfully.

Findings

Before the findings are stated, it must be again stressed that *this study was the first of its kind*, meaning there is no other like it in the literature available. As stated before, these researchers only hypothesized how to terraform another planet, not societal attitudes towards terraforming. This being the case, only descriptive statistics are presented and no form of comparative statistics could be performed. All data can be seen in the Appendix.

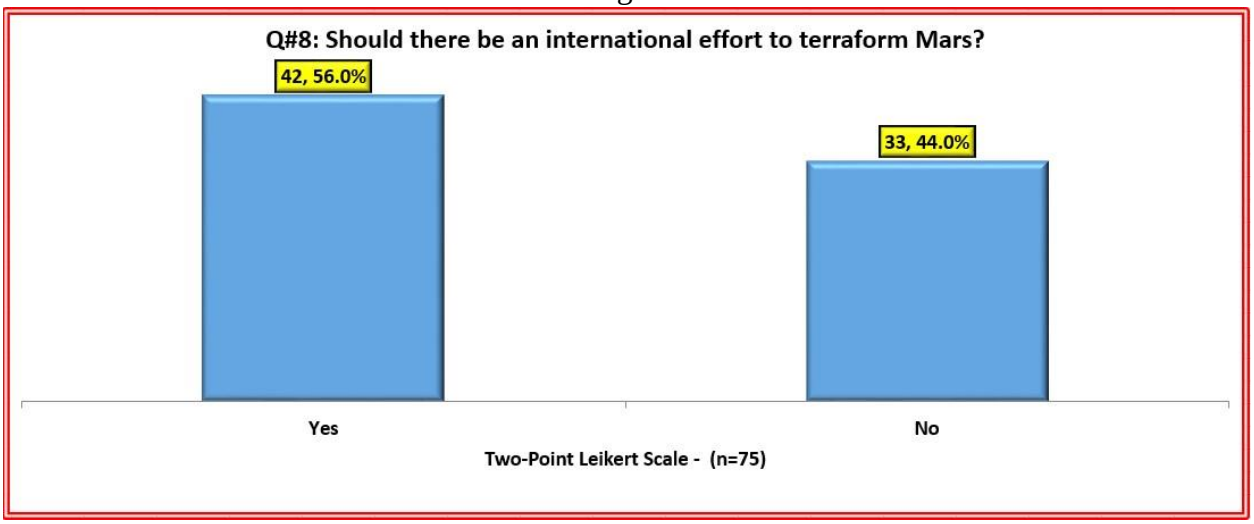
Descriptive Statistics

Histogram 1



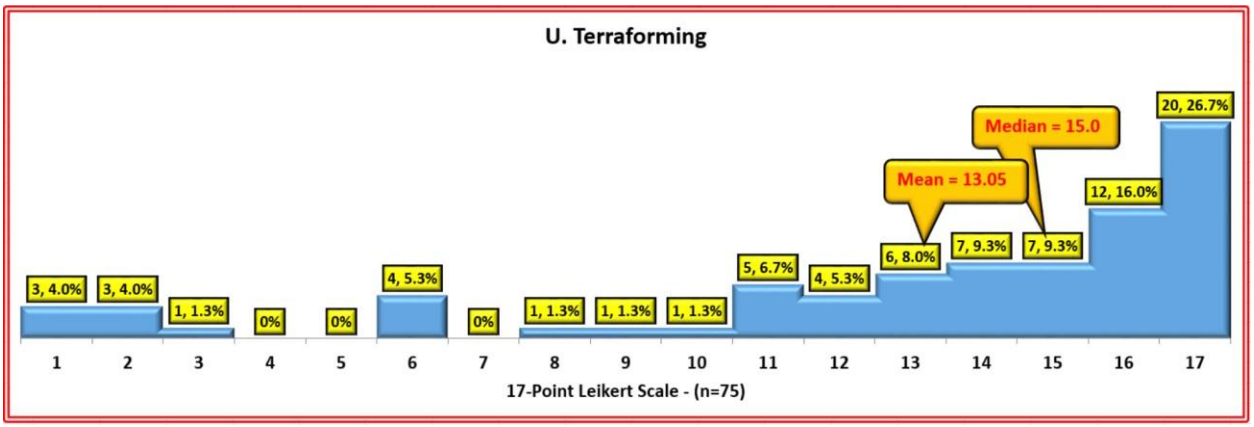
According to Histogram 1, it was found that 61.3% of students surveyed would want to terraform Mars.

Histogram 2

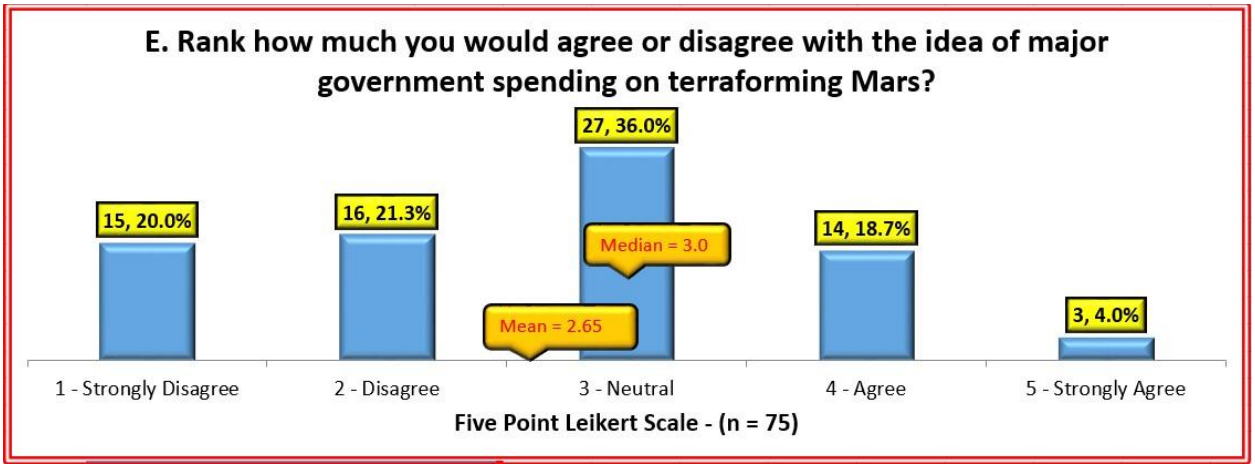


At the same time, when looking at Histogram 2, 56% of students surveyed believe there should be an international effort to terraform Mars.

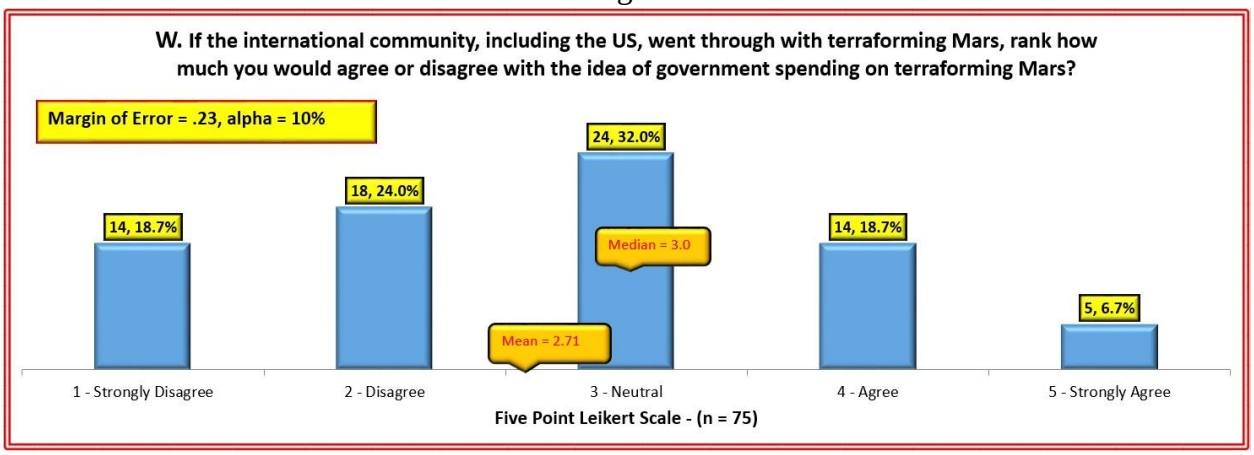
Histogram 3



Histogram 4

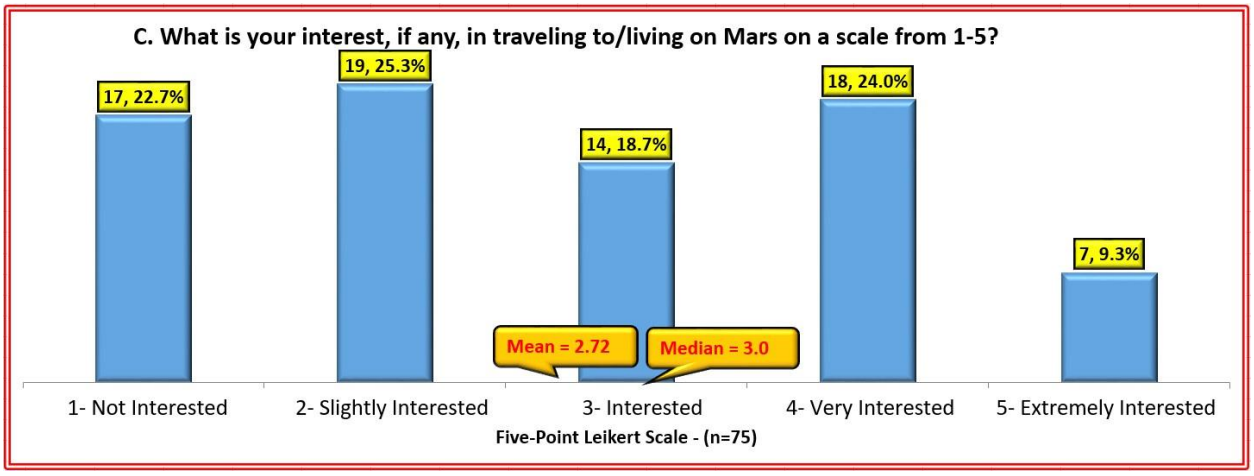


Histogram 5



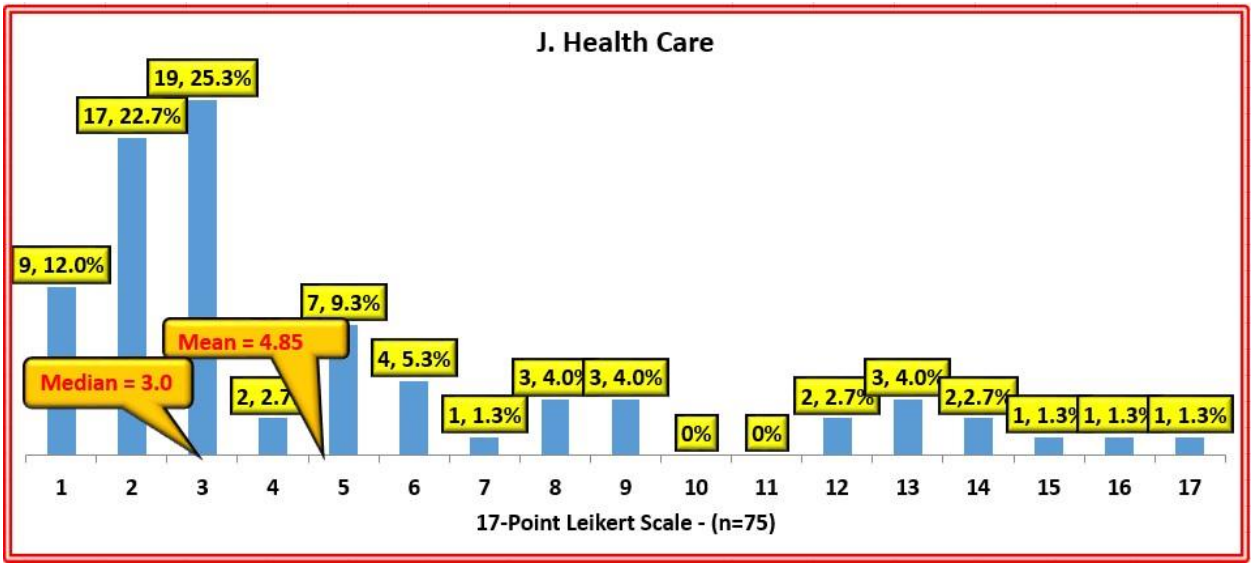
Despite this, the category "Terraforming", when being ranked among 16 other government programs, had the lowest average ranking (13.05) as well as a mode of 17 (27% of participants ranked it a 17). However, this is not surprising when looking at Histograms 4 and 5 where students clearly indicate they are mostly neutral or against government spending on terraforming (41.3% and 42.7% disagreed to some degree, respectively).

Histogram 6

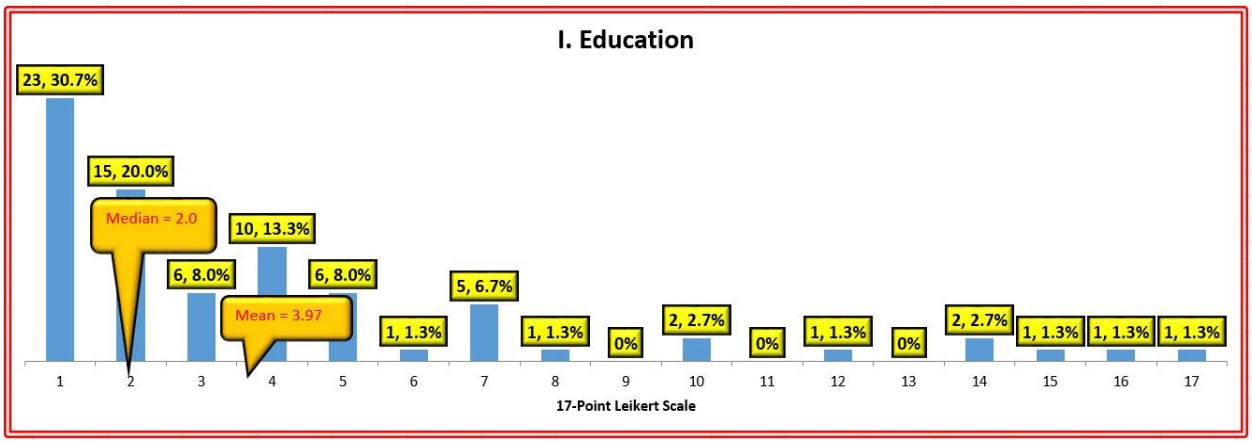


At the same time, the low ranking for "Terraforming" is surprising since the average score for interest on going to/ living on Mars was 2.72, or in other words, there was, on average, a decent amount of interest from the general population in living and traveling to Mars (the mode was 2 which supports the idea there was at the very least some interest in the topic).

Histogram 7



Histogram 8



Students instead wanted government spending to be focused on programs such as “Education” (mean 3.97; mode 1; Histogram 5) and “Health Care” (mean 4.85; mode 3; Histogram 3).

Correlations

	What is y	What is y	What is y	Terrafor	Rank hov	Agricultu	Assistanc	Commur	Educatio	Health C	Immigrat	Internati	Job Trair	Law Enfc	National	Natural F	Reducing	Respons	Science,	Social Se	Terrafor	Veteran	If the int
What is y	1.00																						
What is y	0.06	1.00																					
What is y	-0.09	0.17	1.00																				
Terrafor	0.07	0.11	0.35	1.00																			
Rank hov	-0.23	0.04	0.54	0.45	1.00																		
Agricultu	0.21	0.14	-0.02	-0.06	-0.02	1.00																	
Assistanc	0.30	0.23	0.07	0.06	-0.01	0.24	1.00																
Commur	0.04	0.25	0.05	0.11	0.07	0.42	0.21	1.00															
Educatio	0.06	-0.23	0.32	0.16	0.17	0.06	0.11	0.02	1.00														
Health C	-0.05	0.09	0.38	0.13	0.19	0.14	0.20	0.13	0.61	1.00													
Immigrat	0.04	0.14	-0.10	0.03	0.02	-0.04	0.31	0.16	-0.21	-0.04	1.00												
Internati	-0.03	0.17	-0.26	-0.18	-0.30	0.04	0.21	0.01	-0.25	-0.04	0.32	1.00											
Job Trair	-0.02	0.09	-0.11	-0.03	0.04	0.26	-0.06	0.36	-0.10	0.05	0.15	0.11	1.00										
Law Enfc	0.03	-0.06	0.21	0.06	-0.01	-0.08	-0.11	-0.32	0.21	0.06	-0.11	-0.05	-0.10	1.00									
National	0.03	-0.10	-0.05	-0.01	-0.12	-0.03	-0.24	-0.33	0.04	-0.08	-0.10	0.17	-0.28	0.45	1.00								
Natural F	-0.10	-0.23	0.04	0.12	0.03	-0.05	-0.14	-0.26	0.28	0.12	-0.38	-0.47	-0.26	0.02	-0.10	1.00							
Reducing	-0.27	-0.21	-0.12	-0.07	-0.13	-0.37	-0.42	-0.24	-0.25	-0.54	-0.16	0.04	-0.11	0.14	0.18	-0.06	1.00						
Respons	-0.25	0.12	0.24	0.12	0.32	-0.18	-0.31	-0.12	-0.08	-0.06	-0.25	-0.38	-0.11	0.01	-0.22	0.22	-0.05	1.00					
Science,	-0.14	-0.35	-0.09	-0.04	0.04	-0.34	-0.28	-0.34	-0.05	-0.13	-0.29	-0.33	-0.34	-0.12	0.00	0.25	0.12	-0.01	1.00				
Social Se	-0.01	-0.03	0.06	0.03	0.03	-0.51	-0.20	-0.32	-0.10	-0.13	-0.31	-0.17	-0.46	-0.14	0.07	0.05	0.20	0.17	0.39	1.00			
Terrafor	-0.21	-0.10	-0.30	-0.27	-0.11	-0.30	-0.44	-0.02	-0.61	-0.56	0.01	-0.05	0.09	-0.31	-0.22	-0.09	0.33	0.26	0.15	0.08	1.00		
Veteran	0.26	-0.01	-0.22	-0.13	-0.18	-0.30	-0.20	-0.39	-0.44	-0.54	-0.08	-0.06	-0.11	-0.20	-0.12	-0.12	0.23	0.08	0.23	0.25	0.49	1.00	
If the int	-0.21	0.03	0.54	0.36	0.80	-0.07	-0.06	-0.01	0.32	0.37	0.03	-0.30	0.07	0.22	0.03	0.07	-0.20	0.28	0.02	-0.04	-0.30	-0.29	1.00

There was virtually no correlation (-.11) between the responses for agreeing/ disagreeing on major government spending to terraform Mars and the actual ranking for terraforming Mars. There was virtually no correlation (-.21) between grade and the actual ranking for terraforming Mars. There was virtually no correlation (-.09) between grade and interest in traveling to/ living on Mars. Responses for agreeing/ disagreeing on domestic government spending and international spending had a strong positive correlation (.80). There was a moderate negative correlation (-.61) between the actual ranking for education and terraforming.

Qualitative Findings

For the optional question "Indicate why you would or would not want to terraform Mars", the answers were separated into four separate categories based on the theme they presented. These themes were *Survival, Fun/ Personal Pleasure, Human Expansion/ Innovation,* and *Refrain from Mars*. Since the question was optional, only 51 of the students responded in some way with 7 in the *Survival* category, 10 in the *Fun/ Personal Pleasure* category, 13 in the *Human Expansion/ Innovation* Category, and 15 in *Refrain from Mars* category[7].

Interpretation of Findings

Attitudes Found through Ranking and Written Responses

The data found provides somewhat conflicting results. On one hand, 48% of students have little to no interest in traveling to/ living on Mars. However, more than half of the students want to terraform Mars (either through a national or international effort). Yet, at the same time, "Terraforming" had the lowest average ranking and had 42.67% of its ranking being either 16 or 17. What can this possibly show about societal attitudes towards terraforming?

[7] The remaining 8 responses did not have any of the themes listed above. In fact, most of them seemed to be joke responses in nature (i.e. "There are aliens on Mars", "es un bien opcion").

Primarily, this shows a clear difference between idealism and practicality in students on the subject of terraforming. Ideally, if terraforming was not economically burdensome and required at minimum time and energy, chances are there would be more support (not total support, but possibly more relative to the amount it has now). But when faced with reality, there is no real reason to terraform Mars right now. In the words of one of the respondents, "... we must do so to keep civilization going (**if it is crucial**, if not, then it **doesn't really matter** if we do not touch Mars)". This is the defining characteristic of how teenagers perceive terraforming Mars. If it does not benefit me, why should I support it? Why should I finance it if I will not see it fully realized? While more than half the students would want to terraform and possibly live/ travel to Mars, this does not necessarily imply they would be willing to finance or defund another government program in order to finance such a project because it does not benefit them in the end. Terraforming a planet is a lot of work that will cost a lot of money and take a lot of time. Ultimately, students would want to invest into government programs that could help them sooner than later because it is more practical to them (and by sooner, I mean in their lifetimes). Comparing terraforming with the highest ranked program, education, students would want to invest into the standard of their education because it would help them more now than it would to invest into something they would ultimately never experience.

However, there is more to the story when the written responses are taken into account. What is shown above only takes ranking of government programs into account. The themes found for the optional question indicated earlier gives interesting insight on why students would and would not want to terraform Mars. For starters, 33.33% of total responses wanted to stay away from Mars. One student makes clear that, "We shouldn't take our 'progressive' ideas to another [planet]" saying that we have already ruined our own environment. In fact, a recurring theme among the *Refrain from Mars* group was that we would mess up Mars in the process of

terraforming later down the line. This can be a representation of how high school students feel towards the current status of Earth since they insist on staying put and not "ruining" another planet.

However, the responses were not all negative. In fact, more than half of the responses (66.67%) were positive and supportive of terraforming. The results were, nevertheless, surprising. Most students who want to terraform Mars that also responded to the optional question (15.67%) did not indicate that they wanted to do so purpose of survival. Instead, a majority of students who want to terraform Mars that also responded to the optional question (28.89%) indicated they wanted to do so in order to allow human expansion and innovation. As one students puts it, "We could find new resources/ new form[s] of life and they could find cures to diseases." Another says, "It would give humans an opportunity to not only experience another planet, but also allow the human population to continue to expand". This demonstrates that many students who want to terraform see terraforming as an opportunity to improve humanity.

The Validity of the Attitudes Found

Despite what the data shows, it does not necessarily guarantee that these are the attitudes the students claim they have towards terraforming Mars. In Richard T. LaPiere "Attitudes vs. Actions", he states that, "...there is no necessary correlation between speech and action, between response to words and to the realities they symbolize" and demonstrates through his studies that what participants may write in a questionnaire or survey does not inherently set their actions in stone (LaPiere, 1934). In one study, LaPiere went to many locations scattered across the US with two Chinese friends and recorded his interactions with the various staff in these locations. Afterwards, he called these locations and asked if they would accommodate his two friends and was surprised to find that many of the locations that did accommodate them said "No" despite many of them accommodating them in person. In the same way, these newfound attitudes do not

automatically mean these are what students would say. In short, while the data shows that students do not support government spending on terraforming Mars, it does not mean these attitudes are set in stone.

In terms of the attitudes found from analyzing the students' responses, it must be noted that these students responded to this particular question on a voluntary basis. Due to the nature of the question that was posed, it is possible that those who responded may have had very strong opinions on the idea of terraforming. In other words, the conclusions determined based on the written responses must be interpreted with caution.

Correlation Analysis

Based on the correlations above, the following variables are independent of each other: responses for agreeing/ disagreeing on major government spending to terraform Mars and the actual ranking of Mars, grade and interest in traveling to/ living on Mars, and grade and the actual ranking for terraforming Mars.

Looking back at the correlation between the actual ranking for terraforming Mars and Education, it is implied that those who ranked education highly were more likely to rank terraforming lowly. Again, this goes back to the previously aforementioned idea. Why invest in something that you will never see or be a part of?

As stated earlier, responses for agreeing/ disagreeing on domestic government spending and international spending had a strong positive correlation which, in simplest terms, means that if one was supportive of domestic government spending on terraforming Mars, he/she was also likely to be supportive of international government spending on terraforming Mars and vice versa.

Conclusion

To conclude, teenage Americans attending a large suburban high school in Southern California, while willing to entertain the thought of terraforming Mars, ultimately do not support both domestic and international government spending on terraforming Mars. The reason they do not want to actively spend government funds on terraforming Mars is because they do not believe there is a reason to terraform Mars, with many even saying that they essentially do not want to "ruin" Mars like we have done on Earth. As a result of this research, terraformers are less likely to receive additional funding for their research towards creating an outline for terraforming Mars and the actual process of terraforming is not likely to be discussed in the near future by the federal government.

As mentioned before, a study was performed on high school students attending a large school located in Southern California which was described earlier as a typical high school located in the suburban San Fernando Valley. This means that these results can be generalized to other schools located in a similar suburban setting. In other words, it is believed that students attending a suburban high school will not support terraforming Mars on either a domestic or international level which further supports the conclusion that terraforming Mars is unlikely to happen anytime soon.

Limitations in the research include a limited amount time to give out the survey and access only to a suburban high school. This can be improved upon by sampling Americans in all age groups or in different parts of the US (urban, suburban, rural, etc.) to see the common attitude among Americans as well as identifying which age groups and areas are more/ less supportive of the process. At the same time, the survey can be expanded upon by listing ways Mars could be terraformed that were found in the Literature Review earlier in the paper.

Despite the results from this study, this does not mean Mars will never be terraformed or that students will always oppose government spending on terraforming. As Robert Zubrin puts it, Mars is the next America, the next frontier (Zubrin, 1996). Humanity will eventually find its way over to it. The question is if a colony will ever lead to the planet becoming our future home.

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Appendix

1. Regolith- the layer of unconsolidated rocky material covering bedrock
2. Ecopoiesis- fabrication of a sustainable ecosystem on a currently lifeless, sterile planet
3. AU (Astronomical Unit)- the distance between the Earth and the Sun (92.96 million miles)
4. DV (Delta Velocity)- change in velocity
5. CFC (chlorofluorocarbon)- nontoxic molecules with “a greenhouse effect > 10,000 times that of CO2 [and] residence times of decades to centuries” (Fogg, 1995a)
6. Stellification- the process of making something into a star
7. Albedo- the amount of reflectance of something

Research Analyst: N.T.
Study: SHS Study of Terraforming
Sample Size: n = 75
Survey Design: Stratified Random Sample

1. Where did I meet you?
2. What is your gender?
3. What is your grade?
4. What is your interest, if any, in STEM related fields on a scale from 1-5?
5. What is your interest, if any, in traveling to/living on Mars on a scale from 1-5?
6. Have you ever heard of the term terraforming?
7. Terraforming is the idea of making conditions more human friendly such as clearing forests for agricultural reasons or making a hole through a mountain fo a freeway. Based on this, how much do you agree or disagree with this idea?
8. Terraforming on a larger scale can also change entire aspects of a planet. If one were to terraform Mars, essentially, they would make it habitable for humai Would you want to terraform Mars?
9. Rank how much you would agree or disagree with the idea of major government spending on terraforming Mars?
10. Agriculture
11. Assistance for low-income, unemployed, and disabled
12. Community and regional development
13. Education
14. Health Care
15. Immigration
16. International Affairs
17. Job Training
18. Law Enforcement and Administration of Justice
19. National Defense
20. Natural Resources, Energy, and Environment
21. Reducing the Deficit
22. Response to National Disasters
23. Science, Space, and Technology Programs
24. Social Security
25. Terraforming
26. Veteran Benefits
27. Should there be an international effort to terraform Mars?
28. If the international community, including the US, went through with terraforming Mars, rank how much you would agree or disagree with the idea of government spending on terraforming Mars?

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Research Analyst: N.T

Study: SHS Study of Terraforming

Sample Size: n = 75

Survey Design: Stratified Random Sample

Timestamp	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 9	Question 10	Question 11	Question12
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)17/01/23 9:42:40 AM P	Flagpole	Female	9	3	4	No	3	Yes	4	1	2	3
17/01/23 10:49:11 AM P	Flagpole	Male	11	4	2	No	2	Yes	3	11	10	9
17/01/23 11:02:37 AM P	Flagpole	Male	10	3	4	Yes	2	Yes	3	5	2	14
17/01/23 11:04:49 AM P	Flagpole	Male	10	5	1	No	3	Yes	3	8	12	13
17/01/23 12:31:44 PM P	Flagpole	Female	12	1	1	No	1	No	2	6	16	4
)17/01/23 5:13:47 PM P	Flagpole	Female	10	3	4	No	1	Yes	3	6	8	5
)17/01/23 5:33:07 PM P	Flagpole	Female	10	4	2	Yes	4	Yes	4	9	5	11
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17/01/23 10:48:06 PM P	Flagpole	Male	12	4	5	Yes	2	No	1	10	15	13
)17/01/24 6:48:21 PM P	Flagpole	Female	11	2	3	No	1	Yes	2	8	2	9
17/01/27 10:16:39 AM P	Flagpole	Male	10	5	5	Yes	3	Yes	5	1	2	3
)17/01/30 9:36:14 PM P	Flagpole	Female	10	1	4	Yes	3	Yes	3	17	5	14
)17/02/03 7:17:17 PM P	Flagpole	Female	10	3	2	No	1	No	2	5	4	6
17/01/27 10:02:15 AM P	Flagpole	Female	12	5	4	Yes	5	Yes	3	6	9	14
)17/01/24 1:27:18 PM P	Flagpole	Male	11	5	3	No	3	Yes	3	1	9	8
)17/01/24 7:19:23 PM P	Flagpole	Female	11	4	4	No	2	No	1	8	3	7
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)17/02/01 7:35:40 AM P	Flagpole	Female	11	2	1	Yes	2	No	2	11	12	6
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)17/01/19 8:53:10 AM P	Gate near J and R	Male	12	1	4	Yes	4	Yes	3	6	2	1
)17/01/25 2:59:30 PM P	Gate near J and R	Male	12	5	1	Yes	3	Yes	4	15	6	13
17/01/24 10:37:56 PM P	Hiawatha	Male	11	4	5	Yes	3	Yes	4	5	10	3
17/01/27 10:22:10 AM P	Hiawatha	Male	11	5	1	No	1	No	1	1	15	14
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)17/01/25 7:06:49 PM P	Hiawatha	Male	12	3	3	Yes	5	Yes	3	2	17	5
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)17/01/25 7:06:49 PM P	Hiawatha	Male	12	3	3	Yes	5	Yes	3	2	17	5
17/01/25 10:21:50 AM P	Kingsbury	Male	11	3	3	Yes	4	Yes	3	17	16	15
17/01/25 11:09:34 AM P	Kingsbury	Female	12	4	2	No	3	Yes	2	12	14	9

17/01/25 11:26:19 AM P	Kingsbury	Female	12	4	2	No	1	No	1	15	14	13
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017/02/03 4:48:03 PM PS	Zelzah Parking Lot	Female	9	4	3	Yes	5	Yes	4	7	4	12
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17/01/19 10:06:13 AM P	Zelzah Parking Lot	Female	12	3	4	Yes	4	No	4	10	9	8
17/01/29 10:21:17 PM P	Zelzah Parking Lot	Female	12	2	1	No	3	No	2	14	4	8

Question 13	Question 14	Question 15	Question 16	Question 17	Question 18	Question 19	Question 20	Question 21	Question 22	Question 23	Question 24	Question 25	Question 27
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8	6	5	7	4	12	17	14	3	15	13	16	1	2
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14	13	12	11	10	9	8	7	6	5	4	3	2	1
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1	2	16	10	11	12	17	3	4	13	5	6	14	15
1	3	8	15	11	12	10	9	14	13	6	2	17	16
2	3	6	9	10	7	8	4	12	11	16	13	17	14
2	3	15	8	13	7	9	10	12	6	11	5	17	4
12	9	10	11	16	4	5	1	7	2	8	13	14	15
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15	14	1	10	12	16	17	9	8	7	6	5	3	4
5	4	16	8	17	9	10	2	15	14	13	1	12	11
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1	2	6	16	10	5	17	4	15	7	3	11	14	12
10	9	8	6	3	11	12	13	14	15	16	17	2	1
1	2	5	4	3	9	10	12	11	14	13	15	16	17
3	1	5	11	12	13	14	15	16	2	10	4	17	9
2	13	14	12	16	10	4	1	9	5	3	8	6	7
6	2	8	9	13	11	14	1	17	16	3	5	15	10
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1	3	14	4	13	11	12	7	5	16	2	9	17	15
2	1	3	14	13	12	11	4	10	9	5	6	8	7
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1	2	11	9	12	3	4	16	5	15	7	10	17	6
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1	2	4	3	16	5	6	7	11	17	12	13	14	15
2	3	7	12	13	5	15	6	9	1	16	10	11	17

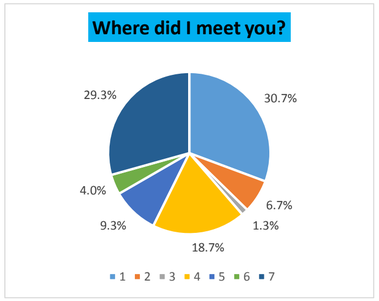
Question 28	Question 29
Yes	3
Yes	4
Yes	3
No	4
Yes	3
No	3
No	3
Yes	2
No	1
Yes	3
No	2
Yes	2
Yes	5
Yes	4
No	3
No	4
Yes	3
No	1
Yes	3
No	2
Yes	2
No	3
Yes	3
Yes	3
Yes	5
Yes	4
No	1
No	2
No	3
Yes	3
No	2
Yes	3
Yes	4
Yes	2

No	1
No	1
No	1
Yes	2
No	1
No	4
No	1
Yes	2
Yes	3
Yes	5
Yes	2
Yes	3
No	3
Yes	3
No	1
Yes	4
Yes	4
No	2
No	1
Yes	5
No	2
No	1
Yes	3
Yes	3
Yes	4
No	2
No	1
Yes	2
Yes	3
No	2
Yes	4
Yes	5
Yes	3
No	1
Yes	4
Yes	4
No	1
No	2
No	3
Yes	4
Yes	2

Research Analyst: N.T
Study: SHS Study of Terraforming
Sample Size: n = 75
Survey Design: Stratified Random Sample

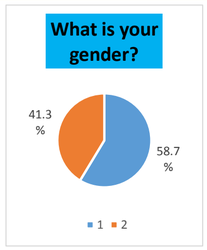
Question 1

Zelzah Parking Lot	23	30.7%
Surface Rd West	5	6.7%
Surface Rd East	1	1.3%
Kingsbury	14	18.7%
Hiawatha	7	9.3%
Gate near J and R	3	4.0%
Flagpole	22	29.3%
Total	75	100.0%



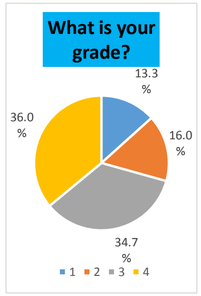
Question 2

Female	44	58.7%
Male	31	41.3%
Total	75	100.0%



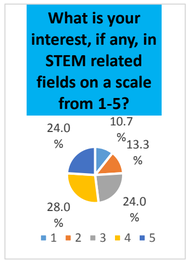
Question 3

9	10	13.3%
10	12	16.0%
11	26	34.7%
12	27	36.0%
Total	75	100.0%



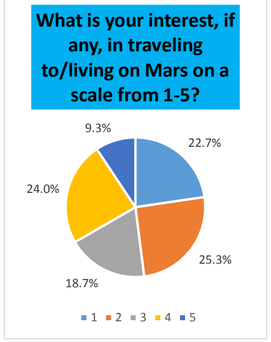
Question 4

1	8	10.7%
2	10	13.3%
3	18	24.0%
4	21	28.0%
5	18	24.0%
Total	75	100.0%



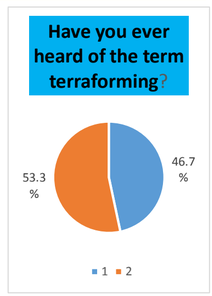
Question 5

1	17	22.7%
2	19	25.3%
3	14	18.7%
4	18	24.0%
5	7	9.3%
Total	75	100.0%



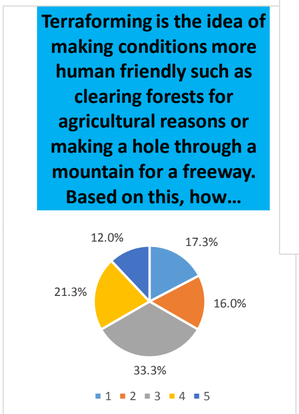
Question 6

Yes	35	46.7%
No	40	53.3%
Total	75	100.0%



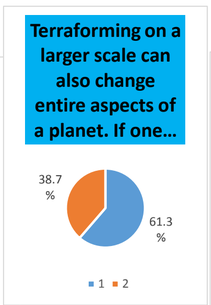
Question 7

1	13	17.3%
2	12	16.0%
3	25	33.3%
4	16	21.3%
5	9	12.0%
Total	75	100.0%



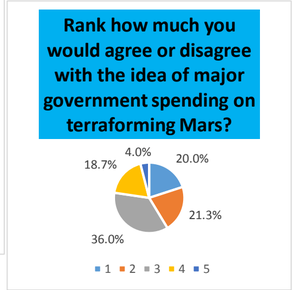
Question 8

Yes	46	61.3%
No	29	38.7%
Total	75	100.0%



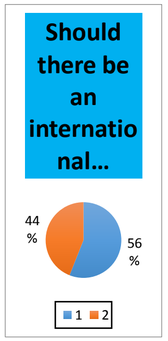
Question 9

1	15	20.0%
2	16	21.3%
3	27	36.0%
4	14	18.7%
5	3	4.0%
Total	75	100.0%



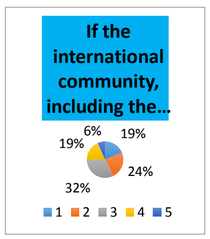
Question 27

Yes	42	56.0%
No	33	44.0%
Total	75	100.0%



Question 28

1	14	18.7%
2	18	24.0%
3	24	32.0%
4	14	18.7%
5	5	6.7%
Total	75	100.0%



Question 10		
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4	6	8.0%
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6	7	9.3%
7	4	5.3%
8	5	6.7%
9	5	6.7%
10	5	6.7%
11	3	4.0%
12	4	5.3%
13	2	2.7%
14	5	6.7%
15	3	4.0%
16	1	1.3%
17	5	6.7%
Total	75	100.0%

Question 11		
1	4	5.3%
2	10	13.3%
3	7	9.3%
4	6	8.0%
5	5	6.7%
6	3	4.0%
7	4	5.3%
8	4	5.3%
9	7	9.3%
10	3	4.0%
11	1	1.3%
12	3	4.0%
13	1	1.3%
14	3	4.0%
15	4	5.3%
16	4	5.3%
17	6	8.0%
Total	75	100.0%

Question 12		
1	1	1.3%
2	2	2.7%
3	9	12.0%
4	2	2.7%
5	4	5.3%
6	4	5.3%
7	6	8.0%
8	9	12.0%
9	4	5.3%
10	4	5.3%
11	3	4.0%
12	3	4.0%
13	8	10.7%
14	6	8.0%
15	6	8.0%
16	2	2.7%
17	2	2.7%
Total	75	100.0%

Question 13		
1	23	30.7%
2	15	20.0%
3	6	8.0%
4	10	13.3%
5	6	8.0%
6	1	1.3%
7	5	6.7%
8	1	1.3%
9	0	0.0%
10	2	2.7%
11	0	0.0%
12	1	1.3%
13	0	0.0%
14	2	2.7%
15	1	1.3%
16	1	1.3%
17	1	1.3%
Total	75	100.0%

Question 14		
1	9	12.0%
2	17	22.7%
3	19	25.3%
4	2	2.7%
5	7	9.3%
6	4	5.3%
7	1	1.3%
8	3	4.0%
9	3	4.0%
10	0	0.0%
11	0	0.0%
12	2	2.7%
13	3	4.0%
14	2	2.7%
15	1	1.3%
16	1	1.3%
17	1	1.3%
Total	75	100.0%

Question 15		
1	1	1.3%
2	2	2.7%
3	4	5.3%
4	6	8.0%
5	5	6.7%
6	12	16.0%
7	7	9.3%
8	5	6.7%
9	5	6.7%
10	1	1.3%
11	3	4.0%
12	3	4.0%
13	6	8.0%
14	3	4.0%
15	4	5.3%
16	5	6.7%
17	3	4.0%
Total	75	100.0%

Question 16		
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6	5	6.7%
7	12	16.0%
8	7	9.3%
9	5	6.7%
10	5	6.7%
11	7	9.3%
12	7	9.3%
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15	3	4.0%
16	3	4.0%
17	3	4.0%
Total	75	100.0%

Question 17		
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2	1	1.3%
3	5	6.7%
4	5	6.7%
5	5	6.7%
6	2	2.7%
7	3	4.0%
8	12	16.0%
9	2	2.7%
10	10	13.3%
11	6	8.0%
12	4	5.3%
13	7	9.3%
14	4	5.3%
15	1	1.3%
16	6	8.0%
17	1	1.3%
Total	75	100.0%

Question 18		
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4	4	5.3%
5	10	13.3%
6	7	9.3%
7	6	8.0%
8	3	4.0%
9	15	20.0%
10	3	4.0%
11	5	6.7%
12	9	12.0%
13	4	5.3%
14	2	2.7%
15	1	1.3%
16	1	1.3%
17	0	0.0%
Total	75	100.0%

Question 19		
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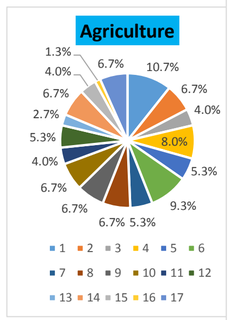
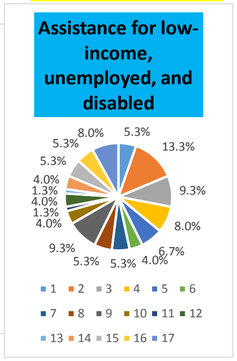
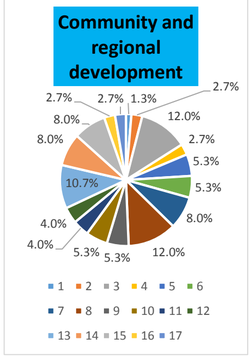
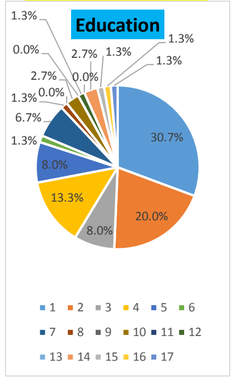
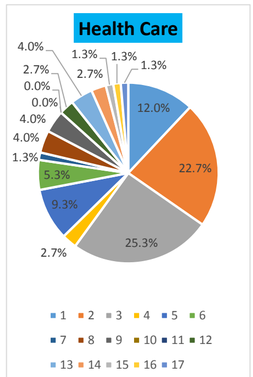
3	3	4.0%
4	4	5.3%
5	8	10.7%
6	7	9.3%
7	3	4.0%
8	4	5.3%
9	1	1.3%
10	14	18.7%
11	5	6.7%
12	3	4.0%
13	0	0.0%
14	5	6.7%
15	6	8.0%
16	4	5.3%
17	6	8.0%
Total	75	100.0%

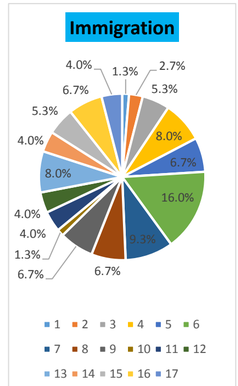


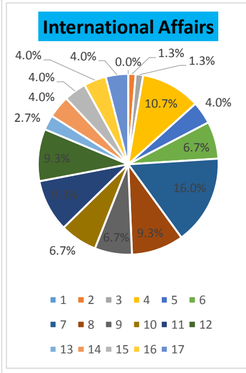


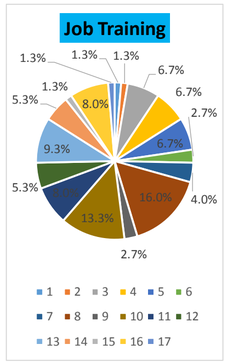


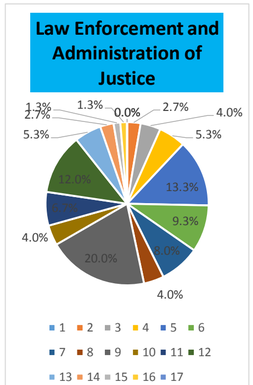


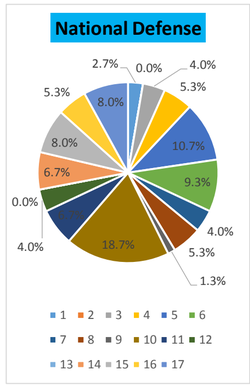












Question 20

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3	3	4.0%
4	8	10.7%
5	1	1.3%
6	6	8.0%
7	7	9.3%
8	5	6.7%
9	4	5.3%
10	3	4.0%
11	11	14.7%
12	2	2.7%
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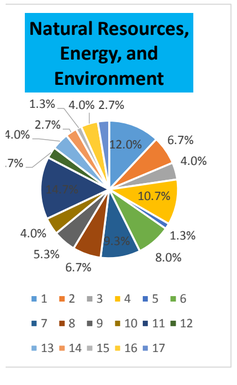
14	2	2.7%
15	1	1.3%
16	3	4.0%
17	2	2.7%
Total	75	100.0%



Question 21

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6	3	4.0%
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12	13	17.3%
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14	7	9.3%
15	9	12.0%
16	4	5.3%
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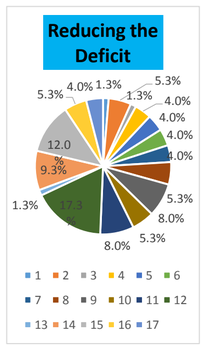
Total	75	100.0%



Question 22

1	4	5.3%
2	4	5.3%
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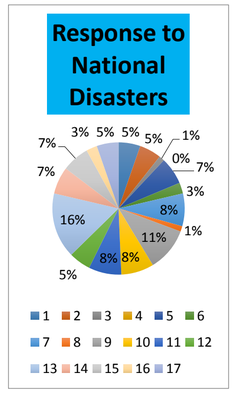
8	1	1.3%
9	8	10.7%
10	6	8.0%
11	6	8.0%
12	4	5.3%
13	12	16.0%
14	5	6.7%
15	5	6.7%
16	2	2.7%
17	4	5.3%
Total	75	100.0%



Question 23

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11	5	6.7%
12	7	9.3%
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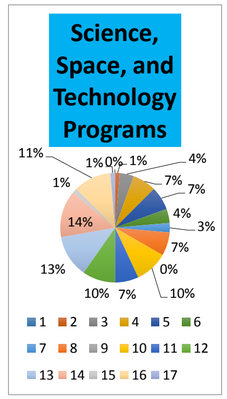
14	10	13.3%
15	1	1.3%
16	8	10.7%
17	1	1.3%
Total	75	100.0%



Question 24

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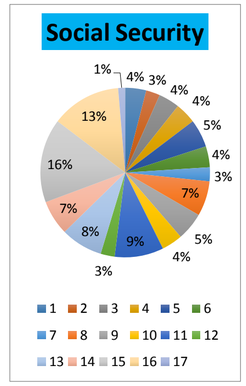
9	4	5.3%
10	3	4.0%
11	7	9.3%
12	2	2.7%
13	6	8.0%
14	5	6.7%
15	12	16.0%
16	10	13.3%
17	1	1.3%
Total	75	100.0%



Question 25

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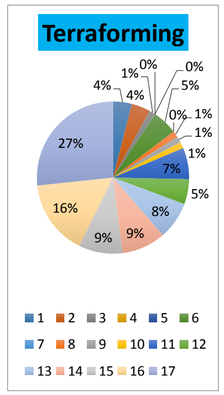
4	0	0.0%
5	0	0.0%
6	4	5.3%
7	0	0.0%
8	1	1.3%
9	1	1.3%
10	1	1.3%
11	5	6.7%
12	4	5.3%
13	6	8.0%
14	7	9.3%
15	7	9.3%
16	12	16.0%
17	20	26.7%
Total	75	100.0%



Question 26

1	6	8.0%
2	1	1.3%
3	0	0.0%
4	3	4.0%
5	0	0.0%
6	2	2.7%
7	4	5.3%
8	1	1.3%
9	5	6.7%
10	4	5.3%
11	2	2.7%
12	4	5.3%
13	5	6.7%
14	4	5.3%
15	10	13.3%
16	8	10.7%
17	16	21.3%
Total	75	100.0%