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Editorial

One of the best parts of my job is working on student-faculty research projects. In early 2018, following ideas I learned at a Community College Undergraduate Research Initiative (CCURI) conference, I put out a call to students at Northwest Vista College (NVC) inviting them to work on a student climate awareness research project that meets our program's Level 3 undergraduate research criteria.

In the Geography and Environmental Sustainability Program at NVC we have four levels of undergraduate research:

> Level 1 - Course-based activity: Short-term (days/weeks), highly structured, research typically common to everyone in class, basic research.
>
> Level 2 - Course-based project: Short-term (weeks/semester), structured, individual research more complex than level 1, includes service learning and study abroad.
>
> Level 3 - Student-faculty collaborative research: Long-term (summer, semester), variable structure, students experience ups and downs of research but are socialized into the profession, includes complexity, written or oral dissemination of results.
>
> Level 4 - External research: Long-term (summer, semester), variable structure, for an organization outside of the college, funded externally, may be called an internship or undergraduate research experience.

The article entitled "Community College Student Climate Change Knowledge" by Allie Sanchez and Farhana Khan, was a Level 3 research project that took nine months from initiation to fruition. While we conducted the research in the spring 2018 semester, we labored over the summer on the data cleaning, analyses, interpretation of results, a review of the literature, and their writing and editing of multiple drafts of the final paper you have before you today. The research Allie and Farhana completed is as rigorous as that of the R1 Doctoral Universities—universities with very high doctoral research activity—from whom we received permission to adapt the survey instrument.

The article entitled "Measuring Water Quantity for Sustainable Use in a Remote Village in the Moroccan High Atlas Mountains" by Farhana Khan and Marcella Palaferri initially fit our Level 2 research criteria. This investigation was conducted as part of the Geography and Environmental Sustainability International Field School project during the summer of 2018. As part of a geography field study class, students gathered data and interpreted those data to meet the class outcomes. I offered to work with any of the six students on formalizing our field work to report to the Atlas Cultural Foundation, a local non-governmental organization. The two primary authors, Farhana and Marcella, accepted the challenge and together we turned this Level 2 research into a Level 3 project. I treated this work like a consulting project following the precedent of Osborne (2016). However, Farhana and Marcella extended the project to include potential community impacts of climate change on subsistence agriculture commonly practiced in the study region.

Soon, all three student researchers will graduate with associate's degrees. I am currently working with Farhana Khan on preliminary tasks involved to move up to Level 4 research—an international internship in Mysore, India. She will be working on a Health, Education, Socio-Economic Empowerment, and Training Research project at the Vivekananda Institute of Indian Studies. Marcella Palaferri was recently hired to work in the Stanislaus National Forest, adjacent to Yosemite National Park, California. Allie Sanchez works full time at the University of Texas Health Science Center and has recently become active in the Texas Stream Team that monitors and records data on Texas waterways.

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Osborne, T. (2016). *Hydrology reconnaissance report Zouiat Ahansal region Aggudim, Morocco*. Billings, MT: Hydrosolutions.

Special Thank You

I would like to offer my great appreciate to Jasmin Ziegler. I asked Jasmin to help copy edit these two papers. Not only did she agree, she got into the spirit of undergraduate research and asked the students in one of her sections of College Writing and Critical Reading to help with this; she used it as a teaching tool and included this task as an assignment in her class. I would also like to thank the students for their efforts. I am certain, with Jasmin's guidance, they learned a lot as they helped make this edition possible. Thanks you!

Matt Schuster
Editor-in-Chief
STAR Journal

Measuring Water Quantity for Sustainable Use in a Remote Village in the Moroccan High Atlas Mountains: Taghia-Ahansal River, Zawiya Ahansal, Morocco

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Farhana N. Khan is a student and tutor in the business department of Northwest Vista College at San Antonio, TX, USA. She is also an intern with the Institute of Business and Entrepreneurship and Student Life Department. Her work experience includes community health educator, logistics support assistant with Humanity First International and mathematics and science tutor. Farhana has a strong interest in environmental studies, sustainable farming, and global health.

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Marcella Palaferri is a May 2019 graduate in Liberal Studies from San Antonio College in San Antonio, Texas. Marcella's previous work history included a 30-plus year sales career in commercial construction. After attending a study abroad program in the High Atlas Mountains of Morocco she is now focused on studying and researching in the fields of anthropology, geography and environmental studies.

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Scott L. Walker is a professor and coordinator of Geography and Environmental Sustainability at Northwest Vista College in San Antonio, Texas, USA. Dr. Walker works with student researchers in order to maximize their applied and experiential learning, to include student-faculty collaborative research, domestic field research programs, and international field study programs in Spain and Morocco.

IRB Statement
This work did not involve human subjects.

Keywords
climate change; Morocco; college students; environmental education; Taghia-Ahansal River; Zawiya Ahansal, Morocco; sustainable water use

Measuring Water Quantity for Sustainable Use in a Remote Village in the Moroccan High Atlas Mountain: Taghia-Ahansal River, Zawiya Ahansal, Morocco

Sponsor Statement

Scott L Walker, ScEdD, Professor of Geography and Environmental Sustainability at Northwest Vista College, San Antonio, Texas, is the sponsoring faculty member on this student-faculty collaborative research project. He has read, critiqued, and edited this manuscript. He certifies that the planning, execution, and writing of this manuscript was conducted primarily by the above-mentioned co-author undergraduate students enrolled at Northwest Vista College at the time of this writing.

Abstract

This study measures the water discharge of the main river in a remote region of Ahansal Valley situated in the High Atlas Mountains of Morocco. The river is the sole water source for consumption, irrigation, and other needs for the inhabitants of four villages dotted around the valley. A team from Northwest Vista College, San Antonio, Texas collected data on discharge, bedload, and the microclimate at four different locations, based on a similar study conducted in 2016. A comparison with the original study data revealed an increase of 400-542% in discharge. This significant change can be contributed to heavy snowfalls in the winter of 2017 and a relatively wet season in the spring of 2018. Despite the current surge, long term data projections from the United Nations and the World Bank suggest a gradual decrease in precipitation in this region due to climate change. A consistent stream monitoring program and effective water conservation plans implemented well ahead of draught periods can support Ahansal Valley residents' sustainability during dry seasons.

1.0 Introduction

Six Physical Geography students and two instructors from Northwest Vista College in San Antonio, Texas visited Aguddim village in the historic region of Zawiya Ahansal, Morocco in May 2018. During our visit we collected data from the Ahansal-Taghia River for water discharge and bed load sample analyses. The sites were selected based in part on a previous report conducted by Thomas Osborne (2016), a professional hydrologist based in Montana, USA.

Student researchers collecting river flow data in the Zawiya Ahansal valley.

1.1 Background

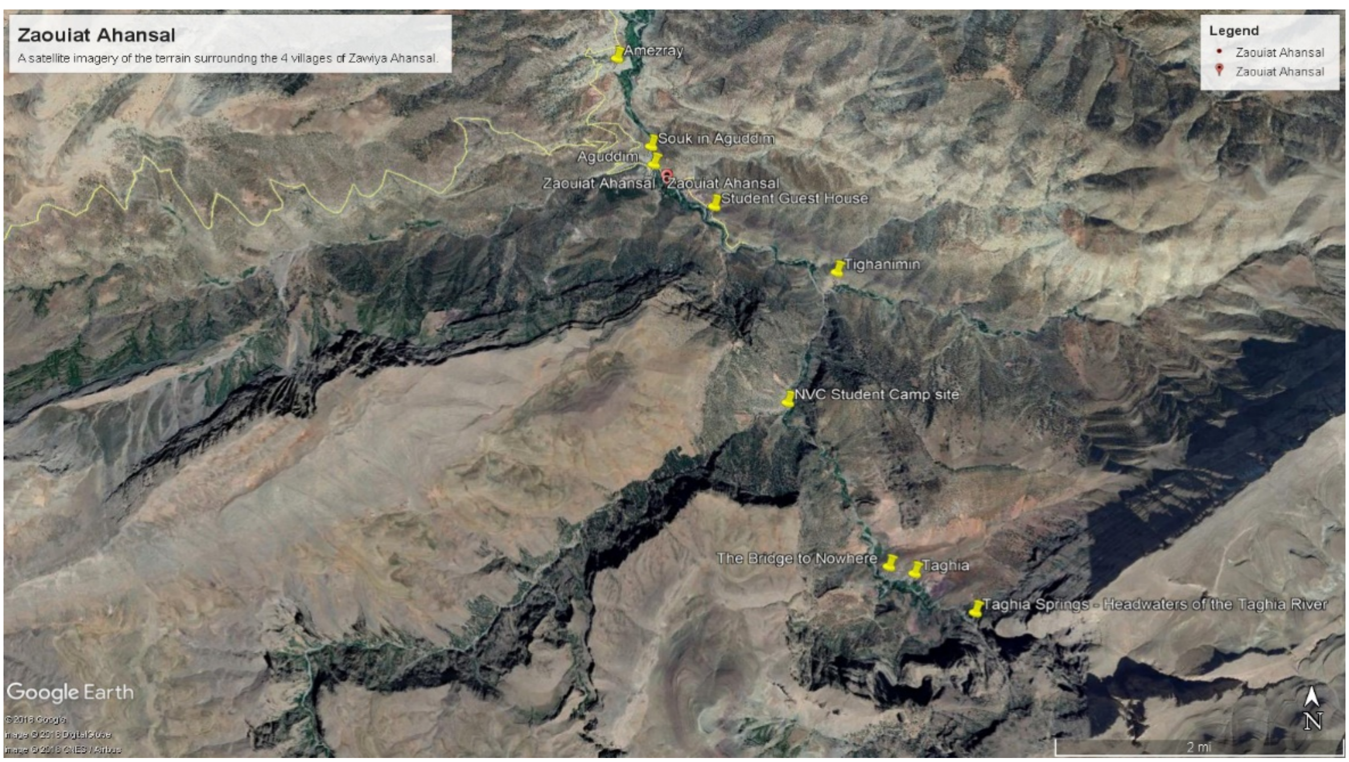
The Zawiya Ahansal region is a cluster of villages in High Atlas Mountains of Morocco. Founded around the 13th century by a Muslim saint, Sidi Saeed Ahansal, the area is known for its historic architectural significance and high peaks that attract avid mountaineers. It has been relatively isolated from the rest of Morocco due to its unique geography. However, recent developments by governmental and non-governmental organizations have increased infrastructure that has allowed for an increase in eco-tourism and adventure tourism. While Ahansalans may appreciate the influx of technological comforts like electricity, roads, telephone service, and internet, they can become weary of increased pollution and limited resources to support the challenges that come with change (Erickson, 2008).

A small percentage of population are employed in wage-earning jobs such as teaching, administration, health, and security. However, the majority of the working population in the region are farmers, pastoralists, or Ait ‘Atta nomads. The total population of Zawiya Ahansal is around 1,500 spread through the valley from the village of Taghia to the village of Amezray (Ismail Barda, personal communication, May 31, 2018).

1.2 Regional Geography, Geology, and Water Resources

The Zawiya Ahansal valley in the High Atlas Mountains is approximately 247 kilometers by road from Marrakech, Morocco. Preceding the steep, rocky inclines of the villages of Aguddim and Amezray, the route from Marrakech reveals low plains and the distinct foothills of the High Atlas region. Zawiya Ahansal's villages are accessible by traveling a major highway from Marrakech, traversing to smaller motorways, and then finally to more tedious, barely double-lane roads with countless switchbacks that climb to more than 1,800 meters before descending to the main villages at just over 1,585 meters above sea level. At the highest level along this trek the land cover is steepe grasses, shrubs, with an occasional tree, typical of this harsh terrain, climate, and weather in the region. Once one reaches the villages an incredibly lush river valley, overflowing with subsistence gardens of the local people is revealed along with a substantial riparian ecosystem. The river is the lifeblood of the local people with the land bestowing fertile valley soil and in turn providing the ability for extensive subsistence agriculture of primarily barley and wheat, with vegetables being secondary to include an abundance of potatoes and turnips, which have been traditionally grown, and more recently introduced lettuces, radishes, beets, onions, and carrots (Ahmed Ousghir, personal communication, May 23, 2018).

Topographically speaking, the region is extremely rugged and steep with Liassic and Jurassic limestone interspersed with sandstone and other conglomerates. The Taghia-Ahansal River system drains from the south at Taghia and Taghia Springs, toward the north passing through the villages of Tighanimin, Aguddim, and Amezray. The plateaus and landscape above the valley floor provide little to no water contributing to a harsh environment that few nomads traverse. The Taghia and Ahansal Rivers are fed by natural springs; however, rainfall and snowpack also contribute to this resource. The valley's steep walls indicate fluvial formation rather than glacial (Gilkerson & Heuck, 2014).



Zawiya Ahansal valley from Taghia in the south to Amezray in the north.

Springing from its source in the mountains near the village of Taghia, the Taghia River—as it is called before its confluence with "Ahansal springs" just south of Aguddim—flows through the Zawiya Ahansal valley past the northernmost village of Amezray, a run of approximately 11.5 kilometers. Several springs feed the stream along the way. The stream and the springs together are the sole source of water for irrigation, laundry, and human consumption through much of the valley. Therefore, an understanding of stream's total discharge and microclimate can be beneficial for understanding this resource. Further, Osborne (2016) recommended repeat water flow analyses and ongoing site photo/re-photo data collection as a part of a comprehensive water-monitoring plan for the valley. This study acts on these recommendations and follows Osborne's stream discharge data collection methods.

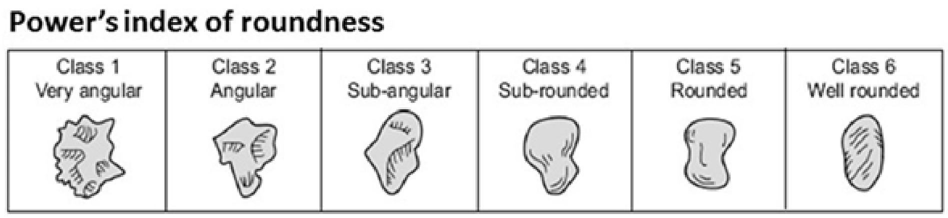
Local women laundering rugs along the Ahansal River (L). Irrigation canal, or sequia, fed by the Ahansal River (R).

2.0 Field Methods

We collected data during in the last week of May 2018. Three of our sampling sites were based on Osborne's (2016) sampling sites. We calculated total discharge using the open channel flow technique. This involved using a meter tape to measure the wetted width of each stream. We divided each width into 3, 5, or 10 equal width sections. At each of these sections we used a meter stick to measure stream depth in order to derive the stream's area.

We calculated flow velocity using a surface float—a dog biscuit in this case. Dog biscuits are lightweight, dispensable, and biodegradable (Field Studies Council, 2016). The dog biscuit method differs from Osborne's floating orange method. At some gauging sites, we collected flow data three times per section and then averaged these for increased accuracy. However, due to time constraints, some sites had only one flow measurement per section.

We also collected bed load data for three of four gauging locations, measuring stream bed load width and roundness. We selected at random at least three bed samples at each section and used a caliper for accurate measurement. We determined roundness using Power's index of roundness, often with three investigators agreeing on roundness for increased accuracy.



(Field Studies Council, 2016)

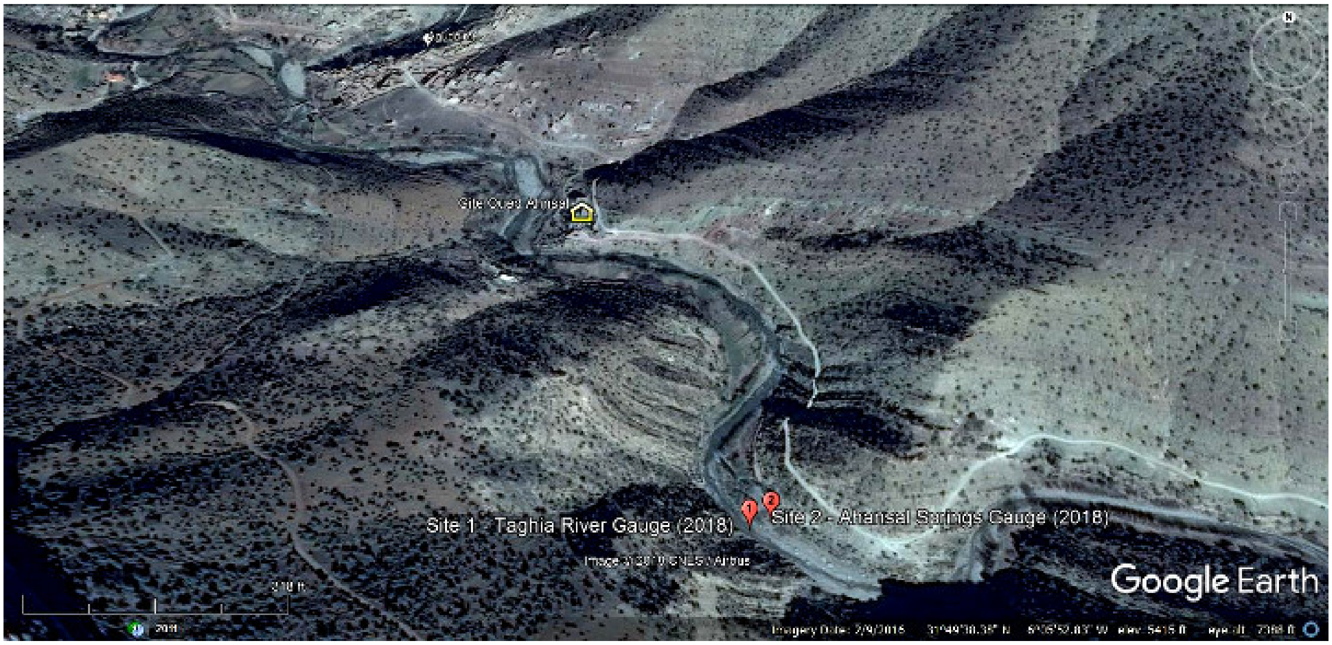
“These data are useful for improving our understanding of the sediment transport processes in gravel-bed mountain streams and rivers, developing and testing sediment transport models, estimating sediment production, and quantifying instream flow requirements for various purposes” (King, Emmet, Whiting, Kenworthy, & Barry, 2004, p. 1). These data we collected and report here are for baseline purposes for future studies.

At three of four sampling sites, we also collected microclimate data for certain parameters, to include:

- Water temperature
- Wind speed
- Air temperature
- Relative humidity

3.0 Gauging Site Data and Results

3.1 Site 1: Taghia River above Confluence with Ahansal Springs



Sampling sites 1 and 2 overall view, south of Aguddim (Google Earth).

Sampling sites 1 and 2 view from road above.

Site 1

Site 2


Site 1 data collection by Northwest Vista College students.

Sample site #1 – Taghia River above the confluence with the flow from the Ahansal Springs was a 6.8 m wide stream segment with a mean depth of 18 cm. Using an error of measure coefficient of 87% (Osborne, 2016), we determined the stream flow at this site to be 1.22 m^3/s (43.25 cfs), which was a 542% increase over the flow measured by Osborne (2016).

Data Collection Date: Friday, May 25, 2018
Time: 10:15 - 11:35 am
Elevation: 1633 m (5357 feet)
Coordinates: Latitude N 31° 49’ 520”, Longitude W 006° 05’ 839”
Water Temperature: 16°C (60.8°F)

Stream Slope: 40°
Right Bank Slope: 4°
Left Bank Slope: 3°

Microclimate Results
Time: 11:45 am
Wind Speed: 10 k/h (6.2 m/h)
Air Temperature: 20.5°C (69°F)
Relative Humidity: 50%

Bed Load: Five samples had a mean size of 8.13 cm with a mean roundness of 4.11 using Power's Index of Roundness. The largest sample was 11.6 cm, while the smallest was 5.5 cm.

Table 1
Bed load sediment analysis results

Distance from the Right Bank (cm)	Width (cm)				Roundness			
Sample	1	2	3	Mean	1	2	3	Mean
136	5.8	6.2	10.5	7.5	5	6	5	5.3
272	11.5	10.6	6	9.37	3	3	5	3.6
408	8.2	8.5	5.5	7.4	5	4	5	4.67
544	6.8	11.3	8.2	8.77	3	5	2	3.33
680	6.7	4.5	11.6	7.6	4	3	4	3.67
Mean				8.13				4.11

Table 2
Discharge data and totals for sample site 1

Distance from Right Bank	Width of Section		Depth	Depth	Float Zone	Time		Velocity	Adjusted Velocity		Area	Discharge
(m)	(m)		(cm)	(m)	(m)	(sec)		(m/s)	(m/s)		(m^2)	(m^3/s)
0.68	0.68		5.5	0.06	1	5.58		0.18	0.16		0.04	0.01
1.36	0.68		13	0.13	5	13.97		0.36	0.31		0.09	0.03
2.04	0.68		22.5	0.23	5	11.3		0.44	0.38		0.15	0.06
2.72	0.68		23	0.23	5	3.55		1.41	1.23		0.16	0.19
3.4	0.68		34	0.34	5	3.2		1.56	1.36		0.23	0.31
4.08	0.68		35	0.35	5	3.17		1.58	1.37		0.24	0.33
4.76	0.68		25	0.25	5	3.35		1.49	1.30		0.17	0.22
5.44	0.68		16	0.16	5	7.09		0.71	0.61		0.11	0.07
6.12	0.68		5	0.05	5	11.97		0.42	0.36		0.03	0.01
6.8	0.68		2	0.02	1	-		-	-		-	-
Width	6.8	Mean Depth	0.18				Adjustment factor		0.87	Total discharge in m^3/s		1.22
							Cubic meter to cubic feet		35.32	Total discharge in f^3/s		43.25

Table 3
Discharge comparison 2016 to 2018 for sample site 1

	Discharge m^3/s	Discharge f^3/s	% Change
Osborne (2016)	0.19	6.61	
Northwest Vista College (2018)	1.22	43.25	+542

3.2 Site 2: Ahansal Springs

Site 2 data collection by Northwest Vista College students.

The original aim of this investigation was to replicate portions of Osborne's (2016) investigation; however, the discharge from the Ahansal Springs was substantial during our study. Below the confluence of the Taghia River and Ahansal Springs (gauged by Osborne, 2016) the flow was dangerously strong; therefore, we altered our sample site by moving upstream from Osborne's 2016 site where stream flow velocity was less and conditions were safer.

Sample site #2 – Ahansal Springs, approximately 80 m above the confluence with the Taghia River was a 18 m wide stream segment with a mean depth of 32 cm. Using an error of measure coefficient of 70% (see Appendix 1) due to fast moving, turbulent water and difficulty wading, we determined the stream flow at this site to be 4.05 m^3/s (143.16 cfs).

Data Collection Date: Friday, May 25, 2018
Time: 12:00 pm – 12:45 pm
Elevation: 1641 m (5384 feet)
Coordinates: Latitude N 31° 49' 31.42", Longitude W 006° 5' 49.80"
Water Temperature: 9.8°C (49.6°F)

Stream Slope: Data not collected.
Right Bank Slope: Data not collected.
Left Bank Slope: Data not collected.

Microclimate
Time: Data not collected.
Wind Speed Data not collected.
Air Temperature: Data not collected.
Relative Humidity: Data not collected.

Bed Load: No bead load samples were collected due to time constraints.

Table 4
Discharge data and totals for sample site 2

Distance from Right Bank	Width of Section	Depth	Depth	Float Zone	Time		Velocity	Adjusted Velocity		Area	Discharge
(m)	(m)	(cm)	(m)	(m)	(sec)			(m/s)		(m2)	(m3/s)
3.6	3.6	48	0.48	2	1.42		1.41	0.99		1.73	1.70
7.2	3.6	30	0.3	2	0.84		2.38	1.67		1.08	1.80
10.8	3.6	15	0.15	2	2.48		0.81	0.56		0.54	0.30
14.4	3.6	20	0.2	2	4.11		0.49	0.34		0.72	0.25
18	3.6	45	0.45	2	-		-	-		1.62	-
Width	18	Mean depth	0.32			Adjustment factor		0.70	Total discharge in m^3/s		4.05
						Cubic meters to cubic feet		35.32	Total discharge in f^3/s		143.16

3.3 Site 3: Taghia River above Confluence with Tighanimin River

Sampling site 3 overview, near Tighanimin village (Google Earth).

Sampling site 3 view from road above.

Site 3 data collection by Northwest Vista College students.

Sample site #3 – Taghia River approximately 60 m above the confluence with the Tighanimin River was a 3.8 m wide stream segment with a mean depth of 27 cm. Using an error of measure coefficient of 87% we determined the stream flow at this site to be 1.04 m^3/s (36.69 cfs).

Data Collection Date: Saturday, May 26, 2018
Time: 11:16 am - 12:02 pm
Elevation: 1681 m (5514 feet)
Coordinates: Latitude N 31° 49’ 173”, Longitude W 006° 05’ 089”
Water Temperature: 15.2°C (59.36°F)

Stream Slope: 2°
Right Bank Slope: 32°
Left Bank Slope: 22°

Microclimate
Time: 11:21 am
Wind Speed: 16.6 k/h (10.3 m/h)

Air Temperature: 20°C (68°F)
Relative Humidity: 60%

Bed Load: Fifteen samples had a mean width of 6.8 cm with a mean roundness of 3.73 cm using Power's Index of Roundness. The largest sample was 10.7 cm, while the smallest was 3.2 cm.

Table 5
Bed load sediment analysis results

Distance from the Right Bank (cm)	Width (cm)				Roundness			
Sample	1	2	3	Mean	1	2	3	Mean
76	4.3	4.2	7.5	5.3	4	4	6	4.7
152	10.7	9.1	5.7	8.5	3	5	3	3.7
228	8.4	10.2	4.5	7.7	4	3	2	7.7
304	6	8.1	3.2	5.8	3	3	4	3.3
380	7.8	5.3	7.1	6.7	4	5	3	4.0
Mean				6.8				3.7

Table 6
Discharge data and totals for sample site 3

Distance from Right Bank	Width of Section	Depth	Depth	Float Zone	Time	Velocity	Adjusted Velocity	Area	Discharge
(m)	(m)	(cm)	(m)	(m)	(sec)		(m/s)	(m2)	(m3/s)
0.76	0.76	20.5	0.21	2	2.73	0.73	0.64	0.16	0.10
1.52	0.76	29	0.29	5	3.47	1.44	1.25	0.22	0.28
2.28	0.76	35.5	0.36	5	3.24	1.54	1.34	0.27	0.36
3.04	0.76	34	0.34	5	4.1	1.22	1.06	0.26	0.27
3.8	0.76	16	0.16	1	3.94	0.25	0.22	0.12	0.03
Width	3.8	Mean Depth	0.27			Adjustment factor	0.87	Total discharge in m^3/s	1.04
						Cubic meter to cubic feet	35.32	Total discharge in f^3/s	36.69

3.4 Site 4: Taghia Springs

Sampling site 4 overview, near Tighia village (Google Earth).


Upstream from sampling site 4, view from below Taghia springs.


Site 4 data collection by Northwest Vista College students.

Sample site #4 – Taghia River approximately 80 m below Taghia Springs, the source of this stream, was a 2.8 m wide stream segment with a mean depth of 41 cm. Using an error of measure coefficient of 87% we determined the stream flow at this site to be 0.55 m^3/s (19.45 cfs).

Data Collection Date: Wednesday, May 23, 2018
Time: 12:30 pm – 1:15 pm
Elevation: 1905 m (6249 feet)
Coordinates: Latitude N 31° 47 '3.96”, Longitude W 006° 4' 6.55”
Water Temperature: Digital thermometer battery died. No temperature recorded.

Stream Slope: No slope data recorded.
Right Bank Slope: No slope data recorded.
Left Bank Slope: No slope data recorded.

Microclimate
Time: 12:30 pm
Wind Speed: 20.6 k/h (12.8 m/h)
Air Temperature: 17.2°C (63°F)
Relative Humidity: No humidity data recorded.

Bed Load: Nine samples had a mean size of 5.9 cm with a mean roundness of 5.3 using Power’s Index of Roundness. The largest sample was 12.3 cm, while the smallest was 3.0 cm.

Table 7
Bed load sediment analysis results

Distance from Right Bank (cm)	Width (cm)				Roundness			
Sample	1	2	3	Mean	1	2	3	Mean
95	6.2	12.3	7.3	8.6	4	4	5	4.3
189	3.0	6.7	4.7	4.8	5	3	5	4.3
284	3.6	4.8	4.5	4.3	6	6	4	7.3
Mean				5.9				5.3

Table 8
Discharge data and totals for sample site 4

Distance from Right Bank (m)	Width of Section (m)	Depth (cm)	Depth (m)	Float Zone (m)	Time (sec)	Velocity (m/s)	Adjusted Velocity (m/s)	Area (m2)	Discharge (m3/s)
0.95	0.95	53.0	0.53	1.00	2.22	0.45	0.39	0.50	0.20
1.89	0.95	36.0	0.36	2.00	3.32	0.60	0.52	0.34	0.18
2.84	0.95	35.0	0.35	2.00	3.22	0.62	0.54	0.33	0.18
Width	2.84	Mean Depth	0.41			Adjustment factor	0.87	Discharge in m^3/s	0.55
						Cubic meter to cubic feet	35.32	Discharge in f^3/s	19.45

Table 9
Discharge comparison 2016 to 2018 for sample site 4

	Discharge m^3/s	Discharge f^3/s	% Change
Osborne (2016)	0.11	4.00	
Northwest Vista College (2018)	0.55	19.45	+400

4.0 Conclusion and Recommendations

This report has presented data from four stream discharge measurement sites with varying hydrology. While locally observed and recorded precipitation data were unavailable, local residents and community leaders referred, on several occasions, to 2018 being a particularly “wet” year and the previous winter having heavier than typical levels of snowfall. Comparisons in our stream discharge results at two measurement sites previously measured by Osborne (2016) two years prior demonstrated a 400% discharge increase at the headwaters of the Taghia River near Taghia and a 542% discharge increase in the Ahansal River at our measurement Site 1 near Aguddim, 11.5 kilometers downstream.

Despite these 2018 observations, climate change models suggest substantial changes in global watershed hydrology in terms of precipitation levels, timing, evapotransporation, and changes in vegetation and groundcover (Gawith, Kingston, & McMillan, 2012). Morocco’s mean annual precipitation is expected to decrease by 14% by 2030 (FAO, 2017) and 17% to 30% by 2050 (FAO, 2017; World Bank, 2018). Rainfall change predictions for Representative Concentration Pathways (RCPs), or greenhouse gas concentration models, of low concentrations (RCP2.6 [+2.6 W/m^2]) for the High Atlas Mountain region indicate the high precipitation month of March might have predominant precipitation changes ranging from approximately -5.47 mm to -9.46 mm, where observed precipitation (1986–2005) was 71.39 mm (World Bank, 2018). High RCP models (RCP8.5) suggest where precipitation decreases it could be as much as -15.2 mm. In the lowest observed precipitation month of July (7.16 mm), RCP2.6 models suggest possible decreases of approximately -1.36 mm to -10.68 mm (World Bank, 2018). Generally speaking, climate change models for this region consistently project a 31% precipitation decrease in the low precipitation months of June, July, and August. Likewise, a potential overall 11% decrease for the high precipitation months of March, April, and May for mid-range future scenarios (MRFS) from the years 2020-2039 (World Bank, 2018).

In terms of agricultural irrigation, having insight to stream flow, as well as groundwater discharge data at primary spring locations along the Taghia-Ahansal River system is important as a knowledge base for each *bab n tarqwa* (father of irrigation), who are annually selected to oversee maintenance and to govern irrigation by those who receive water through the 24 to 26 *sequias* (irrigation canals) throughout the valley (Sheikh Saïd Ahansal, personal communication, May 30, 2018). While this sociohydrological management system has been in place for hundreds of years and administered without quantitative discharge data, in the future the bab n tarqwa, *mkeddm*, *amghar* (community leaders), and subsistence farmers will no doubt be facing water resource challenges related to global climate change. Likewise, the relatively recent drinking water infrastructure and network that relies on adequate Taghia-Ahansal River stream flow may compete with agricultural irrigation for adequate drinking water supply, not only for Aguddim, but also for the roughly 1,500 people who live in this stretch of the valley. Having “good year” stream flow and discharge data will allow regional leaders more information regarding their water resources, which, in this dry climate irrigation region also relates to local food supply resources. If information is knowledge, with recurring hydrological measurements Zawiya Ahansal can avoid or mitigate water shortages similar to those found in other dry mountain regions around the globe (Dörre & Goibnazarov, 2018).

4.1 Recommendations

Regarding this study, we concur with Osborne (2016)(among his other recommendations) that there needs to be a consistent stream monitoring program with consistent sampling and analysis procedures to include documenting discharge at the predominant springs in the valley. A potential way to address this recommendation might be through “citizen science”—that is, teach local residents or high school students how to conduct stream flow data collection and analysis with consistent reporting. Basic stream flow monitoring is often taught at the middle and high school level in Europe and in the United States. Perhaps the Atlas Cultural Foundation could consider adding stream flow monitoring to current supplemental tutoring that already exists for local children and teenaged students. See Appendix 2 for a list of data acquisition hardware used for this study.

4.2 Potential Future Questions to Address

Future questions that might be addressed related to this work are to consider (1) how much additional water will be needed in irrigated areas to offset the yield impacts of climate change?, and (2) among the crops grown locally, which would suffer from a reduced precipitation future?

4.3 Limitations

Limitations to our study have been addressed above, but to recap they include limited time for data acquisition, high stream flows precluding repeat measurements at Osborne’s sample sites as we had intended, and equipment failure (digital thermometer battery). Further, only four sample sites were utilized, limiting our data the information we were able to develop and present in this report.

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6.0 Appendices

6.1 Appendix 1 – Coefficient or Correction Factors

Literature related to coefficients, also called correction factors, varies concerning what level the coefficient should be set. Osborne (2016) used 0.87 and we generally followed this convention. However, the United States Environmental Protection Agency (2012) suggests a coefficient of 0.80 for rocky-bottom streams such as those we measured. The United States Forest Service (n.d.) suggests a value of 0.85. Conversely, the United States Department of the Interior (2001) recommends the following, most of which fall substantially outside of the abovementioned coefficients.

Average depth in reach (ft)	Coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
>20	0.80

(from Chapter 13, section 10)

6.2 Appendix 2 - Data Collection Equipment Used

Equipment Required	Price in US Dollars at Time of Study
(Closed Reel Fiberglass) Meter Tape	$ 25
Meter Stick	$ 5
Dog Biscuits (from Carrefour Market, Marrakech)	$ 3
Notebook	$ 2
Subtotal	$ 35
Equipment Optional	
Clinometer (slope measurement--homemade with a straw, string, washer, and plastic protractor)	$ 1
Compact Whirling Hygrometer (humidity)	$ 25
Weather Gauge (Kestral 2000, Pocket Wind Meter Plus)	$ 95
Waterproof Thermometer (sinking thermometer, analog to avoid need for batteries)	$ 10
Caliper (for bed load measurement)	$ 6
Subtotal	$137

Total	US$172 (MAD1632)

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IRB Statement
The work contained herein was approved by the Internal Review Board (IRB) at Northwest Vista College on March 8, 2018. Contact: Simon van Dijk, Ph.D., NVC IRB Chair, (210) 486-4843, svandijk@alamo.edu

Keywords
climate change; community college; Texas; climate knowledge; scientific knowledge; college students; environmental education

Community College Student Climate Change Knowledge

Abstract
The purpose of this study was to assess the community college students' knowledge of climate change. We administered the *Climate Change Content Knowledge Assessment* to a non-probability sample of convenience consisting of students at Northwest Vista College (NVC) in San Antonio, TX.

Instrument reliability analysis resulted in an alpha coefficient of 0.78. The overall mean score was 41% out of a possible 100% (N = 281). The lowest scores were on items regarding radiation and greenhouse gases. The highest scoring items were related to glaciers, weather, and carbon dioxide. A significant outcome was the difference in scores between genders. Male participants scored 38% on average (n = 141, SD = 0.19) while female participants scored an average of 44% (n = 128, SD = 0.16). Another noticeable trend was between ethnic groups. Asian students scored the highest at 46% (n = 12, SD = 0.14). Hispanic students scored an average of 40% (n = 159, SD = 0.17).

We found that climate change knowledge is limited among the general undergraduate student population at Northwest Vista College. Climate change knowledge has become increasingly important in recent years, and the necessity of educating college students on the subject has proven to be deficient.

Introduction

The importance of understanding climate change has increased significantly over the course of the previous decade. Scientific research has proven that human impact has played a major role in expediting the rate of global climate change and destabilization of the environment (IPCC, 2014). Despite the scientific community's evidence and outcry for mitigation and adaptation, the majority of the global population remain in the dark in regard to basic climate change concepts and understanding. Scientists and environmental activists agree that education needs to be utilized in order to empower younger generations in the struggle against climate change. The doubt and uncertainty of climate change knowledge, noticeable in the majority of the American public, proves that the need for climate change awareness is vital for society to move forward.

Because many college students are working to better impact their future and respective communities, climate change knowledge should be seen as an imperative component in the goal of a sustainable and prosperous future. Although climate education is not required in publicly-funded universities and colleges, raising awareness of the evidence of ecological decline is one way to provide students with the starting point for insight and enlightenment. The first step in attempting to develop public awareness of climate change knowledge is to assess the general population. Because four-year university students have been assessed more frequently in the past than two-year community college students, the research conducted at a community college proved to be a deserving sample. Therefore, we have assessed the local community college population’s climate change knowledge and understanding. The students’ participation was conducted on a volunteer basis with current undergraduate students from all respective disciplinary majors and varying demographics at Northwest Vista College in San Antonio, Texas.

Literature Review

Climate change has been a prominent subject of study for several decades due to the profound impact it has on our collective future as a global community. Researchers have demonstrated that climate change is a global challenge that has been accelerated by humans (Antonsson, Tuba, Slack, & Stark, 2011; National Research Council, 2012). Communities across the globe are facing difficult repercussions due to greenhouse gases (Ramanathan & Feng, 2009). Excess greenhouse gases result in rising sea levels, food shortages (Chen, McCarl, & Chang, 2012), significant temperature increases, and extreme seasonal changes (IPCC, 2014). These issues, among others, stand to threaten the planet’s long term prosperity as the scientific community looks for ways to optimize new energy and economic resources (Prowse et al., 2009). While studies and data have demonstrated the rate of global ecological decline that climate change has imposed on the planet, most people around the world, including college educated adults, do not fully understand the complicated nature of this process and how it works (Cardwell, 2011; McCaffrey, 2015; Sterman & Sweeny, 2007). Although public awareness has increased through media representation (Schmidt, Ivanova, & Schäfer, 2013), the information presented can oftentimes be ambiguous and deceptive (Huertas & Adler, 2012), which deepens the citizenry’s level of misconception.

One noteworthy method to strengthen the public’s knowledge and engagement in conservational efforts is to enhance climate education in schools (McCaffrey, 2015; Radakovic, Petrovic, Milenkovic, Stanojevic, & Dokovic, 2017). In 1975, The Belgrade Charter was proposed at a UNESCO International

Environmental Workshop which created an international framework for environmental education. Environmental education has become imperative as a global effort in the preservation of biodiversity and sustainability (Booth, Jovanovic, Ho, & Miller, 2013). In McCaffrey's research (2015), he suggests introducing updated energy curricula to refine climate change knowledge and embolden future generations to develop new solutions in the race against climate change. Yale University's project on Climate Change Communication (Leiserowitz, Smith, & Marlon, 2010) revealed that while a large majority of the American public (76%) needs more information to form a conclusive opinion on the realities and detrimental effects of global warming, 75% felt that children should be taught environmental education in schools, with 68% agreeing that the United States government should establish the curriculum for publicly-funded education systems.

In recent years, international students have been evaluated to assess their climate change knowledge (Dawson & Carson, 2013; Nigatu, Asamoah, & Kloos, 2014; Radakovic, 2017; Salehi, Nejad, Mahmoudi, & Burkart, 2016). When determining the main climate change informational source, Australian and Ethiopian youth were found to have received the majority of their climate change information through television and media influences (Dawson & Carson, 2013; Nigatu et al., 2014). Multiple studies have also found that climate change topics, such as the greenhouse effect and ozone depletion, have proven to be difficult concepts for global students to fully understand (Bodzin & Fu, 2013; Dawson & Carson, 2013; Rohling, Wandersee, Baker, & Tomlinson, 2016). Researchers have found, however, that students fully understand that climate change is happening now and believe that it is the government and individual's responsibility to adapt (Harker-Schuch & Bugge-Henriksen, 2013). Serbian researchers have found that students respond positively to climate curriculum and are able to comprehend the intricate theories involved (Radakovic et al., 2017). Climate education for students around the world is a fully recognized tool the global community sees as the next step to combat the international dilemma of global warming. Climate change mitigation and adaptation is a complicated process that can lead to a sustainable future, but requires international effort (IPCC, 2014). Comprehensive understanding by students will not only increase the likelihood of mitigation, but knowledge significantly increases the willingness to improve and adapt (Dal, Alper, Özdem-Yilmaz, Öztürk, & Sönmez, 2015; McCaffrey, 2015).

Traditional college-aged students have been specifically targeted for research internationally, as it is this generation who will lead the defense against the threat of substantial environmental decline. University students in Iran were found to have moderate understanding of climate change knowledge, and the students who had studied global climate change previously did not have results much different from the students who had not studied climate change-related courses (Salehi et al., 2016). Research conducted at Drexel University in Philadelphia, Pennsylvania and the University of Delaware in Newark concluded that the undergraduate students who took part in the knowledge assessment exhibited basic understanding, with an overall exam score of around 50% (Huxster, Uribe-Zarain, Kempton, 2015). Studies have also shown that university students in a STEM-related major have responded as more knowledgeable than students studying other disciplines (Nam, 2011; Nigatu et al., 2014). While there is significant academic research examining university students understanding and knowledge of climate change, there are not easily accessible accounts of community college students' knowledge assessment. The present study explores this specific population to better understand the climate change knowledge of community college students in South Texas.

Methods

Population

Northwest Vista College was established in 1995 and is part of the Alamo Community College District. The total population of students at Northwest Vista College (NVC) during the investigation was 16,752. The total number of full-time students was 4,114 and the part-time student population was 12,638. Just over 54% of the total enrollment was female, while 45.9% was male. 73% of the undergraduate students identified as a minority, with 64.6% identifying as Hispanic, 5.7% Black African American, 2.7% Asian, 2% multi-racial, and 1.6% multi-African American, while 22.4% of undergraduate students identified as White. The institution predominantly serves suburban and exurban students with 72% of the population aged between 18-24 and 26.5% of the students population between 25-50 years old (Northwest Vista College, 2017).

Sample

The sample was a non-probability sample of convenience consisting of students enrolled at Northwest Vista College. "Convenience Sampling is affordable, easy and the subjects are readily available" (Etikan, Musa, & Alkassim, 2016, p. 4), thus this is the sampling method we selected so we could gather data rapidly given the parameters of student-conducted research during an academic semester. We will point out that despite being commonly used, volunteer samples are not generalizable and may result in bias, in that the results may not represent the larger population (McMillan, 2004).

Instrument

The instrument we used for data collection was modeled after the *Climate Change Content Knowledge Assessment* (CCCKA)(Aksit, McNeal, Gold, Libarkin, & Harris, 2017). In their original study, students enrolled in geoscience classes (*n*=122) were administered a hard copy pre- and post-assessment of their climate change knowledge over the course of one semester. We modified the original CCCKA that focuses on domain-specific climate change knowledge and perceptions of human impacts on global warming. Before making it available to the general student body, we conducted a field test to assess the usability of our revised version as an online instrument, as well as ensuring that the instrument was mobile ready. The field test also helped determine how long the instrument would take users to complete. We received 28 field test responses. The average response time was 10 minutes for the entire assessment. A commonality in the feedback was that on the items with more than one correct response confused some respondents. In the original CCCKA multiple-choice items with one correct response were mixed in with multiple-choice items that had multiple correct responses. We decided to regroup the items based on their response type. Multiple-choice items with only one correct answer were clustered at the beginning of the instrument, while items with two or more correct responses were listed toward the end.

Distribution/Data Collection

After revising the original CCCKA, we renamed it to Climate Change Knowledge survey (CCK). We then housed it in an online software called Qualtrics, a questionnaire/survey instrument platform. We distributed a link to the CCK to all 567 faculty members at Northwest Vista College (NVC) requesting that the faculty ask their students to complete it either in-class or during their free time. The survey was also offered to 1,645 student members of OrgSync, an online tool run by the Student Life Department that organizes student activities and extracurricular opportunities. The survey was offered during the spring semester to obtain a quick snapshot of student knowledge. It was available for about a month from early March until April.

Results

Of 363 original responses, we eliminated incomplete responses and any responses that took more than 30 minutes for participants to complete. We selected a 30-minute completion cut off due to the fact that most response completions ranged from 5-15 minutes based on the Qualtrics time-to-complete data collection information. Any response taking over 30 minutes suggested that participants might be looking up responses online. Likewise, we eliminated any straight line responses. That is responses that were all zeros or all ones, etc., as those reflect a participant responding without making an effort to actually read the items. After data clean-up we had 281 usable responses.

Descriptive results

Of 281 responses, just over 50% were male, 46% were female and the remaining participants report something other (table 1). The majority of the participants (74%) were between 18 and 24 years old (table 4) and 57% were Hispanic (table 3). Given that the data represented dichotomous values (i.e., correct or incorrect) we used Kuder-Richardson 20 method to analyze reliability, resulting in an alpha coefficient of 0.78, where 0.70 is considered sufficient for this type of instrument and 0.80 is considered strong (Wells & Wollack, 2003). Additionally, we conducted a Flesch Reading Ease test that equalled 68.2, and a Flesch Kincaid Grade Level analysis that resulted in a grade 6.3 reading level.

Table 1
Gender of respondents

Gender Category	Male	Female	Trans-Male	Trans-Female	Gender Variant/Non-Conforming	Not Listed	I Prefer Not To Answer
Responses	141	128	3	0	1	5	3

Table 2 presents descriptive results for the Climate Change Knowledge instrument. The mean score for the entire instrument was 41% of a possible 100% (*N*=281). The overall scores ranged from the highest, $\bar{x}$=0.70, to the lowest, where $\bar{x}$=0.07. Regarding individual items, number 17, concerning information from ice cores had the most correct responses at 197 ($\bar{x}$=0.70, SD=0.43). Item 16, about differences between climate and weather had the second strongest number of correct responses at 195 ($\bar{x}$=0.69).

The descriptive results formulated in Table 2 also illustrate the lowest results for the Climate Change Knowledge instrument. The response range is from $\bar{x}$=0.07 to 0.70. Regarding individual items, number 1, examining solar radiation, had the lowest amount of correct responses at 20 ($\bar{x}$=0.07, SD=0.26). Items regarding greenhouse gases resulted in some of the lowest scores. The two lowest results in reference to greenhouse gases were items 3 and 4. Item 3, addressing the location of emitted photons by a greenhouse molecule, resulted in 39 correct responses ($\bar{x}$=0.14, SD=0.35). Item 4, regarding the amount of absorbed sunlight, resulted in 53 correct responses ($\bar{x}$=0.19, SD=0.39).

Table 2
Climate Change Knowledge survey items, means, and standard deviations

No.	Question	$\bar{X}$	St. Dev
1	Which is the most common form of radiation given off by the Sun?	0.07	0.26
2	What do greenhouse gases do as part of the greenhouse effect?	0.25	0.43
3	Where will a photon emitted by a greenhouse gas molecule most likely go?	0.14	0.35
4	How much incoming sunlight do greenhouse gases absorb?	0.19	0.39
5	Which is the best definition of a positive feedback loop in the climate system?	0.25	0.43
6	Which of the following is the best definition of a greenhouse gas?	0.29	0.46
7	Which is the most common form of radiation given off by Earth's surface?	0.42	0.49
8	Which of the following statements about air temperature change over the past million years is most accurate?	0.28	0.45
9	Which of the following will occur if the amount of ice floating in the ocean decreases?	0.43	0.50
10	How does sunlight affect temperature on Earth?	0.45	0.50
11	Which of the following statements about global warming over the past 50 years is most accurate?	0.60	0.49
12	Which of the following contributes to the transfer of thermal energy from place to place around the Earth?	0.60	0.49
13	Which of the following best describes how plants take in carbon dioxide?	0.62	0.49
14	Which of the following would most likely occur if the oceans stopped absorbing carbon dioxide?	0.65	0.48
15	How has the amount of carbon dioxide in the atmosphere changed since the start of the Industrial Revolution 150 years ago?	0.64	0.48
16	Which is the best description of the differences between climate and weather?	0.69	0.46
17	What information do ice cores from glaciers contain about Earth?	0.70	0.43
18	Which statements about non-greenhouse gases are accurate?	0.48	0.46
19	Which of the following could cause the Earth’s surface temperature to change?	0.22	0.08

20	Which of the following can be caused by climate change?	0.23	0.07
	Average	0.41	0.41

Comparison of Means

In order to explore students' responses by demographic categories we used PASW Statistics 18, to analyze comparisons of means between the participants' ethnicity, age, and gender in relation to their mean scores on the Climate Change Knowledge (CCK) instrument.

Ethnicity

To begin with we conducted a one-way Analysis of Variance (ANOVA) to explore ethnicity and students' CCK scores. The ANOVA demonstrated that the effect of ethnicity on score was statistically significant, F (6, 274)=2.11, *p*=0.05, *N*=281. In order to further explore the relationship between ethnicity and scores, we conducted a post hoc, least significant difference test (LSD)(essentially a series of *t*-tests) that demonstrated the following significant mean difference relationships: Hispanic-White = -0.05 (*p*=0.04), Hawaiian/Pacific Islander-White = -0.17 (*p*=0.04), Other-White = -0.15 (*p*=0.01).

Table 3
Mean scores by ethnicity

Ethnicity	N	$\bar{x}$	SD
American Indian	2	0.26	0.11
Asian	12	0.46	0.14
Black	18	0.40	0.16
Hispanic	159	0.40	0.17
Hawaiian/Pacific Islander	5	0.29	0.18
White	75	0.45	0.18
Other	10	0.31	0.30
Total	281	0.41	0.18

Age

Additionally, we conducted a one-way ANOVA to explore students' age and their mean scores on the CCK. The ANOVA results demonstrated that the effect of age on score was marginally significant, F (3, 270)=2.54, *p*=0.06. In order to further explore the relationship between age and scores, we conducted an LSD test that demonstrated a significant mean difference between the age groups of 18 to 24 year olds scoring a full 10 points lower than those students aged 35 to 44, where the younger, traditional-aged students mean difference was -0.10 (*p*=0.25). Due to low responses from students aged 55 to >85, those categories were eliminated for post hoc analysis (George & Mallery, 2001).

Table 4
Mean scores by age

Age	*N*	$\bar{x}$	SD
18-24	212	0.39	0.19
25-34	34	0.45	0.11
35-44	18	0.49	0.17
45-54	10	0.41	0.18
Total	274	0.41	0.18

Gender

Analyzing mean CCK scores based on gender, using an independent samples *t*-test, males (*n*=141, SD=0.19) scored an average of 38% on a 0 to 100 scale, and females (*n*=128, SD=0.16) scored 44% (*t*(263)=-3.23, *p*=0.001). While we had 281 total responses, we used a sub-sample (*n*=269) for our gender analysis because there were low numbers of responses from non-binary gender categories (table 5)(George & Mallery, 2001).

Table 5
Independent-samples *t*-test for gender and score

Gender	*N*	$\bar{x}$	SD
Male	141	0.38	0.19

Female	128	0.44	0.16

Discussion

The results indicate several points of interest. Ethnicities of the participating students were first analyzed for significant findings. The highest number of responses collected came from Hispanic students, who make up approximately 64.6% of the current student population (Northwest Vista College, 2017). Although Hispanic students make up the majority of the student population, the average assessment score totaled to 40%, resulting in the same average as the 18 Black students who participated. Asian Americans resulted with the highest assessment score of 46% out of the 12 who participated; the White student population followed closely behind, averaging 45% for 75 students. While ethnicities have been evaluated for climate change opinions in the United States previously, (Schuldt & Pearson, 2016) future research can be utilized to further investigate the differences between student's ethnicities and the role it performs in climate change knowledge.

Second, the population sample organized by age provided noteworthy results. The most common community college student age range fell between 18-24 years old, with 212 total assessments averaging the score of 39%. This was the lowest average of all the sample age groups. The highest test score was an average of 49% in the student age range between 35-44 years old, with a total of 18 participants. The reason for this could be that the older population has had more exposure to the subject of climate change, but more research is needed to conclude a reasonable explanation. There have not been significant studies comparing the knowledge basis of college-aged young adults and middle-aged adult students.

A significant discovery was the knowledge differences between gender categories. As previously mentioned, the gender analysis did not include the relatively low number of responses from non-binary gender categories. The male and female test scores did relay that females, although comprised of a lower participation total, averaged 44% on the assessment, whereas males followed behind with an overall score of 38%. These results, while notable, are not unexpected compared to previously recorded findings (McCright, 2010; Nigatu et al., 2014; Radakovic et al., 2017). Past research has also indicated that females generally have a greater concern for global climate change effects (McCright, 2010) and more willingness to adapt and improve conservation efforts (Radakovic et al., 2017). To find out the cause of the gender gap, more research is necessary to accurately assess the difference within the given sample.

Future research is necessary to further the understanding of climate knowledge, and we have several recommendations. The research could include participating students' majors to interpret STEM students' knowledge versus non-STEM major students and what role science backgrounds have on climate change knowledge and perceptions. The assessment can also be given as a pre- and post-survey of Earth Science students, similar to the research from which this assessment was based (Aksit et al., 2017). Assessing income levels and living situations (such as urban vs. rural) can affect climate change knowledge as well (Fusco, 2012). Refining the instrument for future assessment would also be ideal, revising items to increase the reliability and then analyze the validity of the updated instrument. Another recommendation would be for NVC investigators to perform a longitudinal study of the general student population to gauge their knowledge and understanding over time.

Conclusion

In this study we took a quick snapshot of the general student population and assessed their knowledge of climate change. Although this type of research has been previously performed at universities in the United States, as well as abroad, we found that a lack research was available in the community college level of higher education. Thus, we offered the assessment to any student who wanted to participate and then analyzed the results from the study. An average score of 41% was interpreted from the results, and although the total score is considered failing by standard means, it is not far from the results of the study on which our work is based. Students enrolled in an Earth Science course at a four-year university had an average score of 47% at the conclusion of their course (Aksit et al., 2017). Our results indicated that the female students overall performed better than male students. The Asian population scored the highest on the assessment, while the age group who scored the highest were the students between the ages of 35-44 years old. The overall results, however, reinforce the need for updated climate curriculum in a community college setting. This would provide students with a solid foundation of climate knowledge and understanding to further adapt to the reality that is climate change.

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