Summer Bridge/Undergraduate Research Program – Going Remote with COVID-19

Parker, Mary Jo
Executive Director Scholars Academy
University of Houston-Downtown
USA

Benavides, Maria
Jiang, Mian
Qavi, Hamida
Natural Sciences Department
University of Houston-Downtown, USA

Feng, Weining
Xu, Ling
Computer Science and Engineering Technology Department
University of Houston-Downtown, USA

Jegdic, Katarina
Shoemaker, Katherine
Mathematics and Statistics Department
University of Houston-Downtown, USA

Abstract

The goal of a Department of Education MSEIP grant award (P120A190069) entitled ***Enhancing STEM Success*** *targets a program that encourages, prepares, and supports minority STEM students, particularly minority females, to successful completion of the baccalaureate degree. The targeted population focuses on undergraduate years, where transitions and rigor often create barriers targeted by the project. The project addresses these barriers and transitions primarily through mentoring and research skill development. Project Co-PIs (Subject Matter Experts) offered their expertise, laboratories, and creativity for summer mentored research. These rich experiences connect course work to scientific research, thus supporting academic achievement, career investigations, and degree completion. Students were required to generate 8-10 hours of mentored research weekly. In June 2020, the UHD summer research program recruited entering freshmen, transitioning sophomores and juniors lacking experience in research. Due to COVID-19, all mentored experiences were virtual, using Zoom video-conferencing. Thirty-eight participants were accepted into the program.*

Keywords: STEM success; minority STEM research; mentored research; enhanced success

Acknowledgements: Minority Science and Engineering Improvement Program (MSEIP)

Grant number: **P120A190069**, “UHD Enhancing STEM Success through Problem-Solving and Preparation”,

Dr. Bernadette Hence at U.S. Department of Education, and University of Houston-Downtown

1. Introduction

The goal of UHD’s institutional research project, **Enhancing STEM Success,** is to implement a program that encourages, prepares, and supports minority STEM students, particularly minority females, to successful completion of the baccalaureate STEM degree. In this case the targeted population focuses on the first, second, and third years, where transitions and rigor often create barriers the project will address. The project will address these barriers and transitions through six categorical support methods including:

1) Freshman Upstart; 2) Academic Skill Monitoring; 3) Mentoring; 4) Career/Research Skill Development; 5) Leadership/Teamwork Development; and 6) Financial Literacy Skill Development. Because a special focus on recruitment/enrollment and mentoring of females and minorities in STEM with success outcomes as priorities special seminar and workshop series will be dedicated for females including: 1) Summer Bridge Access to high school and community college students through outreach and mentored research; 2) Career workshops with industry partners (e.g., Schlumberger, CenterPoint, NCWIT, Greater Houston Partnership members); and 3) Women Mentoring Women in STEM seminars and mentoring program.

Based on current demographics that Hispanics are likely to become the major ethnic group in Texas by 2030 there is a need for Texas to close the science education gap, recruiting more Hispanic students and other minorities into university STEM degree programs. A clear need exists for more minority undergraduate students across a broad natural sciences, computer and mathematical sciences, and engineering technology degree emphasis to enroll in and complete STEM degrees, thus lessening an educational attainment gap evidenced among minorities (THECB, 2005). Further, ensuring that more minorities and females complete the four-year baccalaureate addresses the THECB 60 X 30 initiative, which promotes access, affordability, success, and cost efficiency for minorities and all collegians. At UHD this includes all degree plans within the College of Sciences and Technology. The ultimategoal of increasing the pipeline of minority students entering into baccalaureate degrees is related to the need for familiarity of the college experience, pre-college academic support, academic monitoring, mentoring by STEM faculty and undergraduates already successful in the STEM arena, broadened exposure to graduate and industry experts and opportunities, research and career exposure, and leadership development through STEM arenas.

Minority students continue to dismiss the four-year university out of fear of the unknown prior to entrance. Minorities, particularly minority women, continue to fail-out of first-year barrier STEM courses as a result of no substantive support services, lack of adequate pre-college preparatory coursework, and/or little to no acculturation into the study hours and techniques needed to grasp rigorous STEM topics as presented in first year courses. First generation minoritiesand females have no historical, familial connections to what the collegiate expectations are for STEM students, thus have the least supportive network available to them once entrance into the STEM degree curriculum begins. This proposal aims to increase the enrollment percent of full-time degree –seeking success rate of minority students, particularly minority women, choosing STEM degrees. Another aim is to familiarize minority students with the rigors and processes connected to successful transition through STEM degree coursework. This aim will be accomplished through three dedicated strategies: 1)Summer Bridge Access to high school and community college students through outreach and mentored research; 2) Career workshops with industry partners connected with the Greater Houston Partnership; and 3) Women Mentoring Women in STEM seminars and mentoring program. Further, other project aims include increases in persistence of full-time minority and female STEM undergraduates and increases in six-year minority and female graduates within STEM fields (See Figure 1.1.).

Because UHD is an urban MSI/HSI university located in the 4th largest metropolitan city in the U.S., the Enhancing STEM Success project is urgently needed to 1) support minority students seeking university degrees through this large university, 2) implement those support components associated with STEM and university baccalaureate degree completion as outlined by this project, and 3) produce verifiable knowledge for other universities, both minority-serving and other, to utilize in the support of the changing demographic constituencies of Houston, Texas, and the U.S. In a 2013 DOED MSEIP award (#P120A130040) UHD made tremendous strides in increasing ABC grade rates for minority and females in first year STEM courses as well as increasing the percentage of full-time minority students enrolled in STEM. Many of the successful strategies will be implemented, but new approaches form the foundation for improved outcomes in the Enhanced STEM Success (seen in Figure 1.1.) illustrates the rising trend in minority graduates by gender indicating the promise this project holds for greater gains. Table 1.1. demonstrates that while gains were made as a result of the previous MSEIP program, there is more important work to be completed through the Enhancing STEM Success project. All tables and figures were developed by the UHD Office of Institutional Effectiveness 2016.

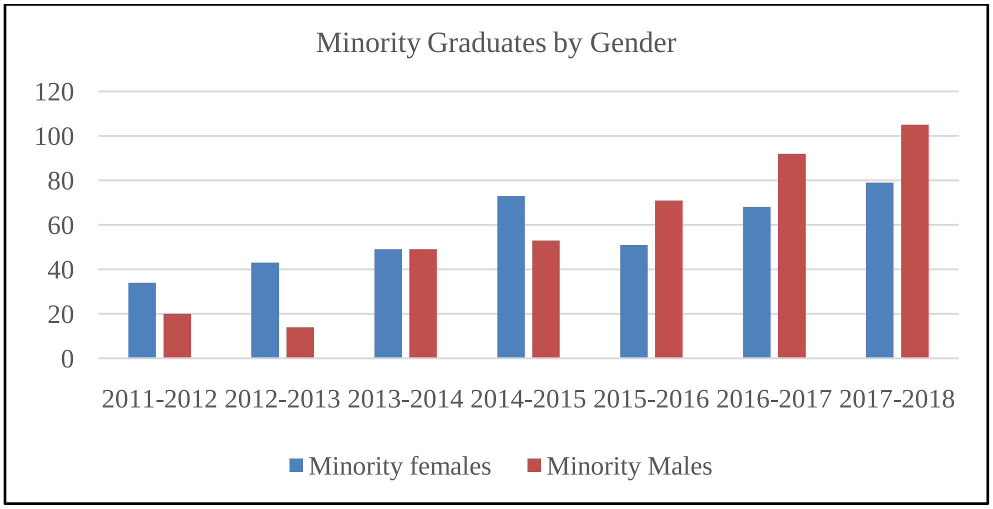


Figure 1.1. Rising trends of STEM minorities by gender graduating.

Table 1.1. Raw Data of STEM Minority Graduates by Gender.

	2011-2012	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**
Minority females	34	43	49	73	51	68	79
Minority Males	20	14	49	53	71	92	105

According to the Texas Higher Education Coordinating Board report (2005, 2015), the state-wide gap between the percentages of white and minorities enrolled in higher education is widening, particularly in the sciences. College enrollment percentages are lower for Hispanics and African Americans and these two groups combined will increase from 42% to 52% in Texas over the next decade. Having lower percentages enrolled and an increasing population translates into a lower percentage of minorities with college science degrees in the future and lower females in STEM higher education and the workforce.

Because of its unique characteristics, geographical location and institutional mission, the University of Houston-Downtown (UHD) plays a pivotal role in the education of Houston's minority populations, females, and those interested in STEM fields. UHD continues to have the most diverse student population of any liberal arts university in the Western U.S. and is recognized as a Hispanic-Serving Institution (HSI) and a Minority-Serving Institution (MSI). After 18 years following the College of Sciences and Technology (CST) faculty creation of the Scholars Academy (SA) whose sole purpose was to increase the number of minority students succeeding in science, technology, engineering and mathematics (STEM) majors through degree attainment and STEM employment, these CST faculty continue to remain involved with the SA to ensure STEM success across the CST.

A much earlier funded 2006 MSEIP award (#P120A050068) within UHD's Natural Sciences (NS) Department allowed for the development of a Summer Undergraduate Research Program (SURP) that was so successful it was expanded last summer to support almost 50 students across all STEM majors. Two common comments from SURP post-program evaluations by students were that 1) they were now interested in graduate school and 2) they wished the program was longer. This project now proposes to incorporate an undergraduate research experience into a more comprehensive STEM support system targeting the increase in minority STEM enrollees and females by including extensive academic monitoring support, enhanced mentored research, leadership and financial literacy development, and an intensive pre-collegiate academic support component in addition to the Scholars Academy (SA) academic unit's student support through small learning communities.

We have identified and recognized several predominant barriers (such as first semester biology, chemistry, mathematics courses; lack of relationships; first generation students having no prior knowledge of what to expect; financial security to persist/complete) to successful retention, persistence, and six-year graduation of minority and female undergraduates pursuing STEM degrees (CUR, 2008; Pender, Marcotte, StoDomino, and Matson, 2010; Kuh, 2008).

These barriers are characterized by several categories of the Enhancing STEM Success project. These barriers are directly addressed by the Enhancing STEM project: 1) Freshmen UpStart support (links FTIC to FTIC, peer leaders, initiates common knowledge of what college is and can be); 2) Academic Skill Monitoring (links peer-to-peer study groups; provides content specialists through tutoring); 3) Mentoring (small learning communities based on discipline; links to link-minded STEM FTIC/faculty/undergraduates; 4) Career/Research Skill Development (career links through seminars/field trips; modeling what research careers resemble by PhD scientists in research; industry seminars; women in industry and academia presenting what STEM looks like for a woman); 5) Leadership/Teamwork/Teamwork Development (service within the community; giving back; producing good works through team efforts; industry partnerships in service); and 6) Financial Literacy Skill Development (hearing, practicing; modeling financial essentials for the college experience; after college experience; loan applications and “small print”). These categories combine to address a new student’s lack of familiarity about what STEM undergraduate degree aspirations really entail coupled with a first generation student’s lack of adequate understanding that a baccalaureate degree is “doable” for them to provide a roadmap of support and experiential learning to support success! This project will implement the categorical support needed for minority and female STEM students to experience success and thus accomplish steady, on-time progress toward degree completion!

2. The Program Components

With the grant’s first year well under way an unforeseen issue arose eventually impacting how mentored research would be performed. The U.S. began to see an explosion of COVID-19 infections. Initially, the COVID-19 thought to have emerged on the east coast, New York City in early March 2020. Later, outbreaks were found to emerge on the northwest coast in Oregon and then much later, very early evidence of December cases were uncovered in San Fransciso, California.

During this time, however, Houston, Texas began to see extremely fast-rising cases and deaths. Houston along with Austin and Dallas were immediately shutdown placing public education and university education in a remote model of learning. Along with coursework, our program administration made the decision with the input from PhD faculty and Co-PIs of the project to take mentored research remotely online in the coming months of May, June, and July. The remainder of this paper provides deep discussion on the part of each of the PhDs as they offer descriptions of the thought processes, creative activities, and deliberate outcomes they implemented and utilized in guiding undergraduates, novice in research, through a principled and deeply meaningful research project. While the project would continue as the new fall semester (August – December), a very strong five-week program allowed the novice undergraduate researchers to attach themselves to research as a possible career.

2.1. Research within the Natural Science Department

2.1.1. Computational Chemistry – Dr. Maria Benavides (students-Nick H,Jeff C, Angela V)

Three undergraduate students participated in computational chemistry research during five weeks in the summer; two of the students were sophomore Chemistry majors and one student was an incoming freshman. In order to pursue their research projects, each student was granted remote access to a research computer using the application “RemotePC Viewer”. The students and the PI met on a weekly basis as a group in order to review important aspects of basic computational chemistry and quantum chemistry, as well as the specific computational methods applied in their research projects. In these group meetings, the PI trained the students into how to model their compounds, run the calculations, and interpret the data produced in the calculations. In addition to the group meetings, each student met individually with the PI in order to discuss their progress in their assigned project and to troubleshoot any problems encountered in their computational projects.

Each student was assigned a different conjugated dye in order to learn how to apply the computational techniques, with the objective that each student would be assigned an individual research project in the summer or the following semester, that consisted of transition metal complexes recently synthesized for each there are no published computational studies. The program used to run the calculations is Gaussian 16 (Frisch, *et al.*, 2016) in combination with the GaussView (Dennington, et. al., 2016). These are commercially available programs that are widely used in the scientific community to conduct computational chemistry research. These programs are housed in various research computers. The calculations consisted of: (a) modeling of the conjugated dye compound using GaussView in order to obtain an “guessed” structure that will be used as an initial input, (b) geometry optimization in order to obtain the most thermodynamically stable geometry of the compound, and

(c) frequency calculations in order to confirm that the optimized geometry corresponds to the most thermodynamically stable structure, as well as to produce Infrared (IR) spectra that will be then compared to the experimental Infrared (IR) spectra in order to assess the accuracy of the predicted models as well as to conduct vibrational analysis. The calculations were run using Density Functional Theory (DFT) in combination with two basis sets, 3-21G and 6-31G.

The calculations yield important molecular properties that allow us to study the chemical nature of the compounds in greater depth, such as: (a) dipole moments which allow us to determine the polarity of the compound; (b) the highest occupied molecular orbital (HOMO) – lowest unoccupied molecular orbital (LUMO) energy gap, which is indicative of chemical stability, (c) molecular energies, and (d) molecular orbitals analysis.

During the five weeks in the summer, the students were able to model their assigned conjugated dye, but only one of the three students, a sophomore Chemistry major, was able to successfully run all the calculations. The other sophomore Chemistry majors was partially successful in running the calculations; this student and the PI attempted to trouble shoot the calculations, but working remotely made it very difficult to resolve some of the issues that the student was encountering while attempting some types of calculations. Had these same problems occurred in the regular face-to-face interaction, the PI would have been to have direct access to the computer and resolve the issues. The incoming freshman student was not able to run the calculations successfully. Unlike the other two sophomore Chemistry majors, this incoming freshman student had not taken any undergraduate chemistry courses, so she found herself in a disadvantageous position as she was finding the theoretical foundation of this computational chemistry research too challenging. She attempted to run the calculations, but it was obvious that she lacked an understanding of basic chemistry and the research techniques presented to her.

Figure 2.1.1. shows the optimized geometry of one of the three conjugated dyes, obtained by the student who was able to run the calculations successfully, while figure 2.1.2. shows the computed infrared spectrum of this dye.

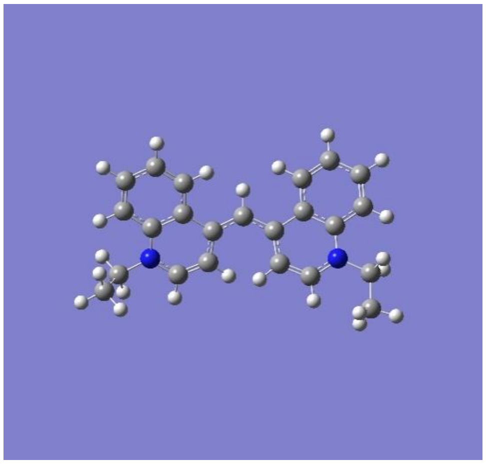


Figure 2.1.1.: Optimized geometry of 1,1'-diethyl carbocyanine cation.

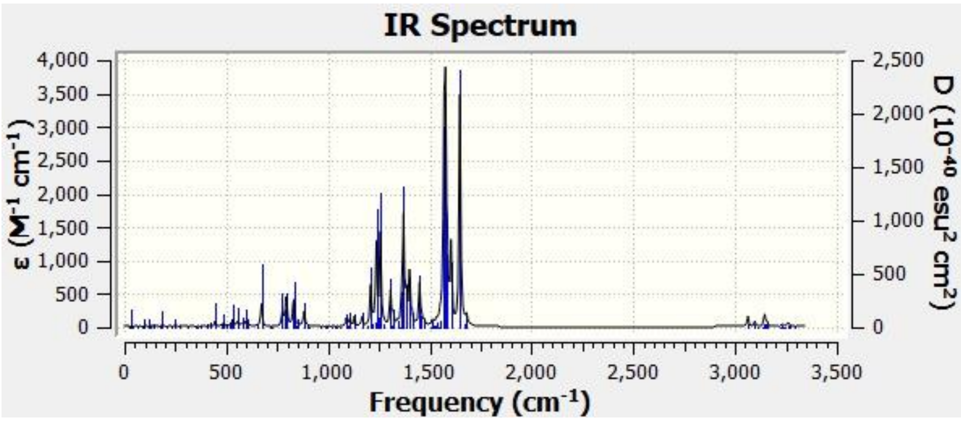


Figure 2.1.2.: IR spectrum of of 1,1'-diethyl carbocyanine cation.

At the end of the five summer weeks, the two sophomore chemistry majors expressed that they had deepen their understanding of chemistry and that the research experience was very positive, although they admitted that they found some of the concepts required to conduct this research, advanced. The incoming freshman student did not provide much input regarding her personal experience, but the PI suspects that it was challenging for her. As a group, the students indicated that the program “enhanced the hands-on experience as well as the familiarity of working in a research environment.

2.1.2.Cancer Research – Efficacy Determination of Anticancer Components from Plant Products – Dr. Hamida Qavi – (students – Abigail R, Stephanie N, FNU A)

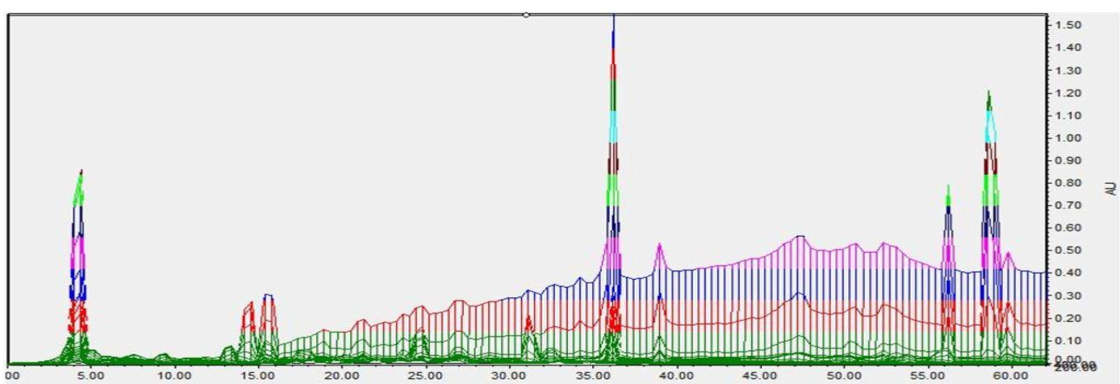
Conducting research remotely has been an innovative and exciting way of doing research with Undergraduate students. In summer 2020, three students were engaged in performing research online and successfully completed the assignment. They learned how to search for literature, designed experiments and submitted their findings as a new proposal for the next semester to execute it.

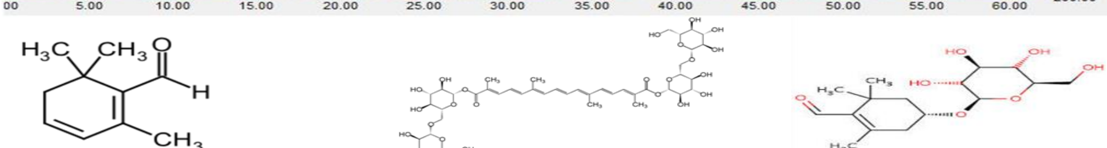
It is anticipated that the experience gained by the students will motivate them to pursue their higher education, support critical thinking, and increase the likelihood of success in graduate school and industrial work. This experience will also provide better preparation for professional/graduate programs, and greatly inform choices as to what careers as a research scientist is truly like. Engaging in High Impact activities is common in scientific careers.This project was supported by MSEIP and it is gratefully acknowledged.

The main purpose of this study is to isolate and characterize anticancer agent(s) from saffron and test their efficacy using Breast cancer cells in vitro. The current project involves isolation, purification and identification of anticancer agents from plant products including Neem Leaves, Saffron, Peral Garlic, Turmeric roots, Black Peppers and Solanum Nigrum Leaves. Further studies are required to evaluate the safety and efficacy of these agents in the cancer treatment. Isolation and characterization of biologically active anticancer agent(s) from the above mentioned plant products have not yet been fully characterized and determined their anticancer efficacy against Breast Cancer Cell lines.

2.1.2.1. The components from the plant products have been extracted using mixtures of polar and non-polar organic solvents with variable ratios and purified using Silica gel column Chromatography and High Pressure Liquid Chromatography. The isolated components were identified by Thin Layer chromatography and subjected to anticancer efficacy determination using MCF 7 cancer Cells and MCF A10 normal epithelial cells in vitro.

2.1.2.2. A few of the findings from this research are presented below. These studies were performed by undergraduate students at UHD. In a preliminary study, the efficacy of a crude methanol extract from saffronwas determined on growth of MCF7 (Breast cancer cells) and MCF10A (Normal breast epithelial cells). The components from this fraction showed minimal growth inhibition of MCF10A, however 70-75% MCF7 cell growth was inhibited in vitro. This saffron fraction was further purified using High Performance Liquid chromatography (HPLC) and the anticancer efficacy data indicated that three of 12 fractions collected from the HPLC column showed 55-80% growth inhibition of MCF7 cells as compared to MCF7A10 cells. These components now being characterized structurally using NMR and GCMS spectroscopy.

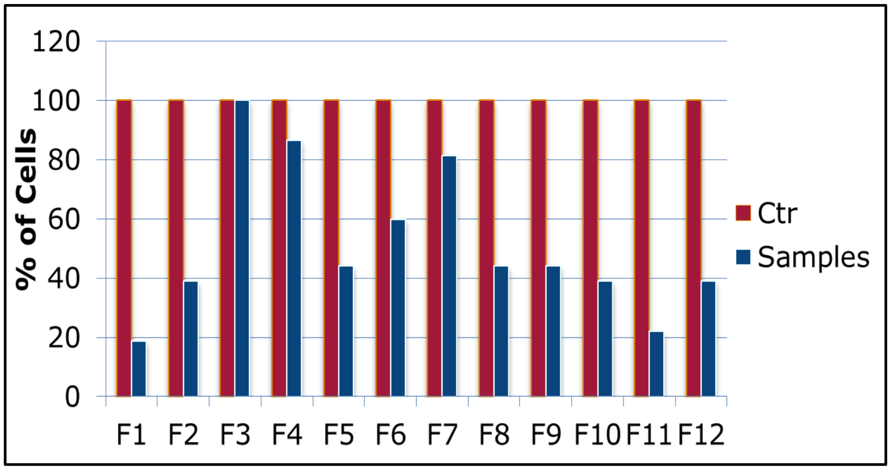




Safranal (Aroma) Crocin (Color) Picrocrocin (Taste)

Fraction #1Fractions # 5 – 7Fraction #11

2.1.2.3. The purified saffron fraction was further purified by using a High Performance Liquid Chromatography (HPLC) and the results are shown in the diagram above.Anticancer efficacy data of 12 fractions collected from the HPLC column are shown in the diagram below.



Components from purified fractions are now being identified using Thin Layer chromatography (TLC) and will be subjected to structural characterization using Infrared (IR) spectroscopy, Nuclear Magnetic Resonance (NMR) spectroscopy and Gas chromatography (GC) analyses About three to four compounds are isolate and purified from each of these sources such as Saffron, Turmeric, Pearl garlic, Thyme and Purple basil. Identity of most of these compounds is unknown (Not available in the Literature). Therefore, in the next step, Nuclear Magnetic Resonance (NMR) Spectroscopy will be utilized to determine their structures and identity. NMR Spectroscopy is one of the most useful analytical techniques for determining the structure of an organic compound. Also, NMR interpretation plays a pivotal role in molecular identifications.

2.1.3. **Water quality determination based on household items in the Pandemic period – Dr.MianJiang**(students – Aracely G, Rachel M)

Working remotely from a central chemical facility has been a new way of doing research during the Covid-19 period. Water quality monitoring, combining both field testing and environmental addressing to the pandemic, fits the student-centered needs of both hands-on exposure/operation and remote learning that lie in the educational mission of MSEIP.

Our preliminary work focused and developed qualitative and semi-quantitative methods for the field testing of pH as it is one of the most important quality parameters, and this would lead a way to expand into other parameters. These methods were based on household chemicals and items that are available during the pandemic period.

Our work laid in two aspects: the choice of the best pH indicator from grocery items as the qualitative measure (acidic or basic), and the semi-quantitative pH determination based on the indicator selected and a home-made pH titration assembly. The starting materials were pH-sensitive indicator dyes extracted from vegetables including red cabbage, beet, red onion, white onion, and other colorful vegetables and fruits. The extraction time, temperature, and air-exposure were studied. The extent of freshness of grocery vegetables on the pH-sensitive dyes were compared. Red cabbage showed the best indicator capacity because of its distinctive color-change scale upon broad pH range responses. Extracted dye from red cabbage also exhibited the longest thermos stability and anti-oxidation feature when exposed in air. The pH indicator pigment that exists in the extracted dyes, per existing literature, is pigment molecule flavin that belongs to anthocyanins cluster. For the novel design of a portable and disposable pH testing kit, we developed the home-made pH test paper after comparing various available paper substrates including paper towel, A4 premium printer paper, coffee cup filtering paper, Kimwipe paper, and packaging paper. The optimal choice, coffee filtering paper, was found to be the best handy qualitative identification of pH because of its composition and texture.

To extend our home-made pH indicator and its novel associated kit (pH test paper) into a more quantitative or semi-quantitative measure of pH, was another focus in water quality monitoring. A simple titrating assembly was designed based on household items including syringe or straw pipe and cups. It aimed at the pH quantification at extreme pH condition (strong acidic or basic), and the quantification of unknown environmentally-significant species found in water bodies such as potassium hydrogen phthalate, carbonate, phosphate, and sulfate.

The titration assembly was tested for its general titrating capacity by using colorless acid and base solutions found in household (muriatic acid, borax, baking soda, and vinegar) with red cabbage dye indicator. The sharpness of the color change upon completion of the acid-base titration was examined by various factors such as temperature, addition of salt, quantity of the added indicator, and the titration sequence. The resultant titration graphs were drawn in comparison to the ideal strong acid ~ strong base titration graphs with phenolphthalein indicator (from literature). Our Covid-19 research approach did offer an alternative semi-quantitative assay for unknown extreme pH environment as well as ordinary determinations of unknown samples that are carried out under conventional acid-base titration.

In addition to the novel design and application of the research discussed above, this student-centered MSEIP project offered training for both hands-on and minds-on opportunities for participants in literature search, engineering design, remote sensing, field testing, and practicability of the cook-book principles "in touch with" real life such as Covid-19. Participants were excited for their discovery, progress, and the presentations originated from this study.

2.2. Research within the Computer Sciences and Engineering Technology Department

The Development of Moto Learner – a Mobile Application for Kids' Education- Dr. Ling Xu (students – Ubaldo R, Armstrong O)

2.2.1. Motivation

As mobile devices increase in popularity, applications for mobile platforms have been widely created for various purposes. They are flexible and portable to use. The interactions provided by the mobile applications provide more engagement than that of static traditional media such as static books or webpages. In this project, we developed an app for education purpose. The field of STEM education is seen with a lot of stigmas mostly from the abstract and complicated concepts and mechanisms and lack of evidence-based practices and tools. This is especially obvious for the early education for kids (McClure, et.al., 2017). With this project, we expect to provide an educational software for kids and invoke their interest in mechanics, engineering, and related STEM fields.

2.2.2. Procedure, Tools, and Outcome

We chose an interesting topic that attractive to many kids – how does a car work? Our application will teach kids the definition of a car, the components of a car, how the pieces are assembled and work together, and the basic mechanic knowledge of a car. The introduction is presented as minilessons with short videos, colorful pictures, and audio effects and music that are friendly for kids. The user interface involves the factors designed for the convenience for kids' use, such as buttons, radio buttons, scroll bars, and so on.

Two UHD undergraduate students participated in the development process, mentored by a CS faculty member. Their work includes three major phases: Design and Prototyping, Implementation, and Assessment, as detailed in the following.

In the design and prototyping phase, the Engineering student focused on the module design work. He prepared the material about cars and mechanics and designed the modules of the application. The other student is in the CS major. He designed the interface conceptual model for the software. Their work is shown in Figure 2.2.2.1.

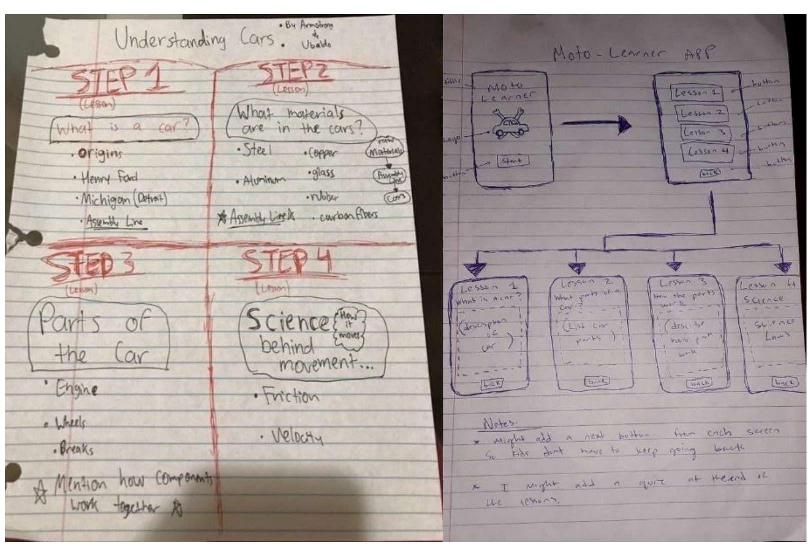


Figure 2.2.2.1. Concept and Prototype Design

The implementation of the application is completed using Android Studio, a platform for mobile app development. Due to the difficulties from Covid-19, the student-student and student-faculty communications took place online using Zoom. The students used online tools such as GitHub for the project collaborations. In this phase, the elements that are attractive to kids are widely used, such as bright colors, cartoon styled characters, animations, background music, and simple diagrams. When introducing the knowledge, we use plain and short text to explain the professional concepts. The text size and font are also friendly to kids. Figure 2.2.2.2. shows several screens for Moto Learner, which contains the above described elements.

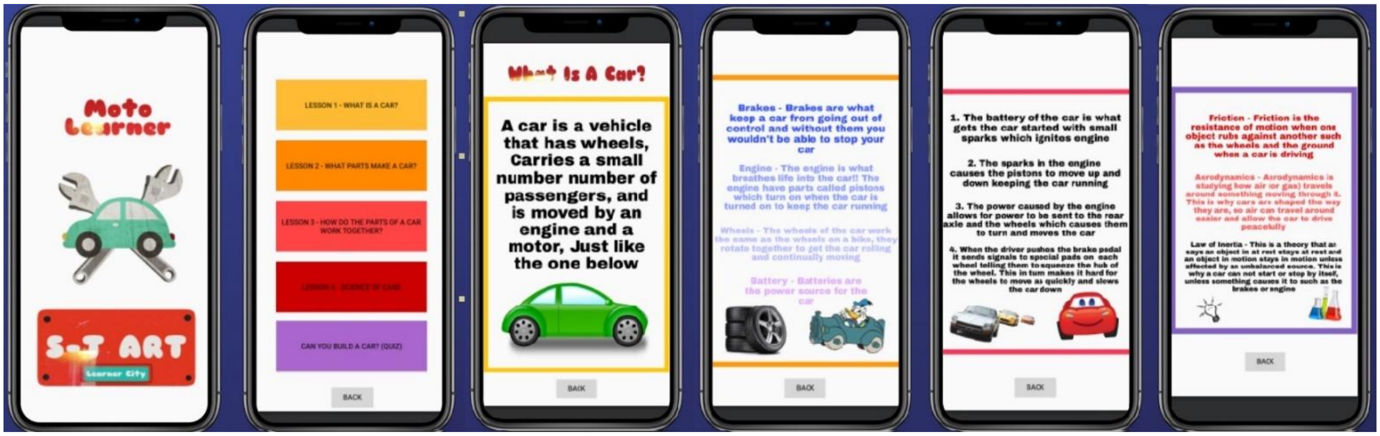


Figure 2.2.2.2.. Screens of Moto Learner

The third phase is assessment. To test the functionality of Moto Learner, we did the first study within the team. In the second round, we invited other undergraduate students to use our application, and collected feedbacks about different aspects of performance, including aesthetics, effectiveness, and convenience for use. In our future work, we will collect feedback data from wider users such as kids and their parents.

2.2.3. Dr.Weining Feng, Engineering Technology(students – Minh N, Paolo S, Brenda V)

Three students conducted summer research projects with Dr.Weining Feng on engineering technology related topics. Students aimed their effort at in-depth understanding of subject specific theories, in conjunction further development of core skills such as programming for engineering application, power electronics modeling and simulation, and programming using JavaScript for operation system independent Apps. Three research projects are outlined below.

2.2.3.1. Structural dynamics study via vibration analysis:

This project focused on structural dynamics characterization for the prevention of civil engineering failures. Analysis of structural vibration measurement data was conducted with Fast-Fourier Transform method, in which frequency responses were derived to show the natural frequency of a structure. At the initial stage of the project, vibrational analysis was conducted on a vibration data sample. Excel macros, and VBA, were used to automate the computational process. An VBA program was developed which successfully automated the calculation process and produced spectrograms from the vibration sample data. The application program created will aid in the development of a structural dynamic testbed.

2.2.3.2. Power Conditioning in PV Based System - Charge Controller Optimization:

In a photovoltaic power system, the charge controller plays a crucial role in maximizing electric power conversion in a reliable and safe manner. A literature survey has been conducted into well-known algorithms implemented in various charge controller models: Fractional Open Circuit Voltage (FOCV), Perturb and Observe (P&O), and Incremental Inductance (IC). It is desired to create a benchmark system to evaluate the performance of each of these algorithms and serves as a platform for developing an optimized algorithm for charge controller implementation. A parallel activity was modeling of charge controller power electronic design with the intent to build a prototype system for benchmarking purpose. The simulation model will be used for sizing key power electronic components and serves as a reference model for prototype system verification. This project is part of a multi-stage research endeavor. Follow-up work is still ongoing, and progress will be reported at a later point.

2.2.3.3.Application for UHD Parking Information System:

At University of Houston-Downtown, students and faculty members often have difficulty in finding parking spaces. Despite having four parking garages, they are in different sites without any ways to notify incoming drivers the vacancy status of each parking lot. As a result, drivers have to spend time driving around multiple parking lots to find a parking spot. This research proposes to develop a parking information system with a mobile application to provide real-time vacancy notification of UHD Parking lots. The Parking information system consists of a database with real-time data on the numbers of vehicles in each of parking lots. A mobile application which connects to the database provides visual display of vacancy status of parking lots. The main purpose of the application is to enable students and faculty members checking available parking spots when driving to campus, so that they can drive directly to the parking lot with free spots, avoiding wasting time circulating at other parking unnecessarily. The key requirement for the app is to be cross-platform, which can be run on both iOS and Android. It is not feasible for the researchers to have two teams developing the app in iOS native and Android native. Therefore, the researchers chose to develop the app in JavaScript using React Native library. With the help of React Native, the front-end of the app is deployable on both major platforms, iOS and Android. To handle the back end or server side of the application, the researchers decided to use Node.js library and MongoDB database. They are supported for JavaScript, which makes it easier to develop and maintain the client side as well as the server side for having the same programming language. Further communication with UHD IT department will take place to evaluate the feasibility of App deployment.

The research program also placed emphasis on oral communication and teamwork. Each research student gave stand-up talk at weekly team meetings, presentingproject progress and discuss potential solutions for issues encountered. These meetings offered opportunities of cross-discipline pollination and team building, as students learned from each other, and supported each other by asking critical questions and offering constructive suggestions. The continued effort in engaging undergraduate research activities has a significant accumulative effect, which is reflected by research students outstanding competence in overcoming challenges. One of the research students had participated TAMU Datathon 2020 competition (371 participants) recently, coming out awarded with 1st prize for his team's entry.

2.3. Research within the Mathematical and Statistics Department

Dr. Katarina Jegdic(students – Rafael G, Salman K, Ashly G) **and Dr. Katherine Shoemaker** (students – Victoria L, Azfar V, Dei Sharrah A, Lan D)

2.3.1. Project 1: Numerical study of two-phase flows in vertical pipes

Dr.Jegdic's team included three students who just joined University of Houston – Downtown in summer and were at the freshmen/sophomore level (summer bridge students). One student majored in data science and the other two in computer science. To accommodate the requirement that the project should be completed in five weeks, considering students' mathematical background and level, a project with a less theoretical and a more computational approach was conducted.

The background problem was related to two-phase flows of gas and liquid in vertical pipes being modeled as a one-dimensional partial differential equation subject to certain conditions. Since the students did not learn about derivatives before the project started, a short introduction to average and instantaneous rates of change of a function was presented, followed by the statement of the differential equation in question. Afterwards, a detailed development of finite difference methods for solving differential equations was taught along with their implementation. Two main components of the project that allowed students to fully participate in it and actually make some contribution in a very short time were:

- The project involved a real-world phenomena and students were able to connect the mathematics topics they were learning with actual applications, and
- The project was less theoretical and more computational to allow students to participate in writing codes and obtaining graphs of the approximate solutions.

The requirements that the project must be completed within five weeks and that it must be conducted virtually made this project both challenging and very different compared to Dr.Jegdic's previous experience in working with undergraduate students. Some of the main points are the following.

1. The program had to be fully organized and prepared. A detailed schedule of meetings and material to be covered along with expectations was set in advance and Dr. Jegdic tried to follow it without any modification.
2. A folder on Blackboard Learn (LMS) was created where all the material related to the project, including meeting recordings, was posted.

3. Virtual 1-hour meetings were conducted twice a week where all three students were asked to participate. In the case where a student was unable to participate, they were asked to watch the recording prior to the next meeting. Agenda for each meeting was prepared in advance and shared with students prior to the meeting.
4. Dr. Jegdic sent emails few times a week for a continuous communication and to keep students engaged and working on the project. Various handouts and reading materials, in addition to being posted on Blackboard Learn, were also emailed with detailed instructions. Students were also asked to do literature search on their own related to applications of differential equations and topics in multiphase flows.
5. During the code implementation and presentation preparation, the students were asked to schedule a meeting and work together. This enforced "teamwork" even though these students never meet face-to-face.
6. End of program presentation marked the end of the project and enabled students to review the material they learnt and to get a wider perspective of the project. The students divided the work into three parts and each student explained their own part:

- physical background of the problem,
- development of a finite difference scheme, and
- computational results.

7. The last meeting of the program was used to give students an insight about possible future work on utilizing artificial neural networks to solving differential equations.

The main challenge of conducting this project virtually was the lack of social interaction. Effective teaching involves a two-way interaction and the virtual environment did not allow it to the same level as a face-to-face environment. Some of the challenges that Dr. Jegdic experienced are the following.

- In face-to-face teaching, most of the time a student's facial expression is sufficient for a teacher to see whether the student understands the concept.
- During virtual meetings, it is hard for an instructor to determine whether the pace at which he/she is presenting is fast and also the students are not as comfortable to stop the instructor and ask questions.
- It is not clear whether the students are taking notes or just watching the screen. Certainly, in understanding mathematics, just watching the screen is not enough for gaining understanding and it is important that a person writes down the notes and pay attention to each detail.

Dr. Jegdic believes that the project was beneficial to students' education experience and that it enhanced their collaborative, communication, and presentation skills, as well as their computational, analytical, and critical thinking skills. This was evident by students' end of project virtual presentation and by the fact that all three students decided to continue this project in the fall semester.

2.3.2. Project 2: Exploring novel emergent data using data science techniques

Dr. Shoemaker's students were at varying levels of experience and exposure to data science. Three of the students majored in data science, one of the three had taken her introductory data science course the previous spring, and the other two were enrolled in that course the upcoming fall, and the fourth student majored in Applied Statistics with a focus on secondary mathematics education. As was expected in this program for early career students, their programming and statistical skills were limited, when presented.

To capture how data science is an emergent field where one is often working on topics that are quickly developing and evolving, the students were divided into pairs and were given projects related to the intersection of data science with the SARS-CoV-2 virus (COVID-19). The projects were designed to capture the momentum of the moment and to span the entire data science pipeline; giving the students exposure to all aspects of the process and procedures that are necessary to be a successful and flexible data scientist. The first project looked at the infection rates for the nine counties of the Greater Houston area and demographic information about those counties, and the second project was in a sense a meta-analysis of the field's response to the emergent virus, looking at the rate at which academic papers were being published on COVID-19 in journals with various attributes in data science and related fields. Students were asked to do a guided literature search at the outset of the projects, and they were guided in developing their own plan of approach to the analysis.

These projects were designed to have the students the experience the full spectrum of the process: collect and gather their own data, clean and process it to get it ready for analysis, then perform exploratory data analysis (EDA) to find relationships and associations between these variables, if any. The students were guided through these steps by Dr. Shoemaker, highlights below.

For both pairs, the research began with a general introduction to data science, the data science pipeline, Exploratory Data Analysis, and a concentrated overview on utilizing R to do these tasks.

The research could not be fully prepared ahead of time, as each step depended on the findings of the previous steps, but a general outline was set, and Dr. Shoemaker was able to prepare and provide the needed resources on demand as the findings were explored.

Each student pair had a scheduled weekly meeting with Dr. Shoemaker, to discuss current progress and the plan going forward. As there were only two per group, if a student was unable to make a meeting, it was rescheduled.
For each project, Dr. Shoemaker was in contact with a domain expert, and they gave guidance to the project and the students as needed.

For the demographic data project, the students worked with Dr. Goltz, Associate Professor of Social Work at the University of Houston-Downtown, an Adjunct Assistant Professor of Infectious Diseases at Baylor College of Medicine, and Research Investigator at the Michael E. DeBakey VA Medical Center. For the journal project, the students worked with Mr. Ring, the Math and Statistics subject librarian at UHD.

Both pairs of students were given help and assistance from the domain expert, but of particular interest is that the students who worked on the journal project were given a training session by Mr. Ring, that covered using the UHD library resources for accessing the available journals and finding information about them such as impact factor and whether they are open access, variables collected for the meta-analysis.

A team was setup in Microsoft Teams in order to facilitate file sharing, communication, and meetings. Each pair of students was given a channel in which they could chat with each other, Dr. Shoemaker, and the domain expert for their project. Files were shared using the synced cloud drive functionality of Teams and SharePoint, and meetings were held in the pair's channels, allowing the meetings to be recorded and stored. These channels encouraged collaboration between the pairs on a platform that could be monitored and validated by Dr. Shoemaker.

Teaching computational skills such as EDA using statistical software like R was difficult virtually, but the chat feature of Teams allowed for a high level of interaction throughout the week; the students were able to immediately reach Dr. Shoemaker with issues or findings. This proved to be incredibly useful, as Dr. Shoemaker found one of the most difficult aspects of teaching programming remotely was debugging. Students were able to reach her quickly, provide screenshots of the issue, and she was able to address those issues virtually and quickly so that they could proceed with the research. This allowed the students to stay engaged with the project throughout the week and not get held up by an easily addressed barrier. While this cannot be compared to previous experiences, as this was Dr. Shoemaker's first experience with student research, this chat functionality is something she will continue to use in the future, even as research moves back to face to face settings.

Beyond the challenge of a narrow time frame and limited skill sets of the students, these projects also presented the challenge that, as with all such novel research in data science, an interesting or significant result was not guaranteed. However, Dr. Shoemaker feels as though the lack of definitive outcome does not detract from the learning experience of working hands-on with new data that was collected by the students themselves to answer these new emergent questions, and getting the experience of working with domain experts. The students were able to experience the data pipeline from beginning to end, even in this short time span, and they were able to get a taste of what it is like to scrape and work with real and messy data. Further, the two students that are continuing with Dr. Shoemaker in the fall are going to be able to use data they collected to explore additional modeling techniques to seek out relationships and associations in the data.

2.3.3. Conclusion

The common features of the above projects are that they each focused on applications to real word phenomena, employed computational techniques, and utilized virtual platforms. Since Dr.Jegdic's project outcomes were predictable, it allowed for the program to be fully prepared in advance. On the other hand, Dr. Shoemaker's project gave students an opportunity to experience research through discovery where each step depended on the findings of the previous step. Through the modifications and additional steps detailed above, both projects were successfully led and overseen virtually.

3. Project Conclusion

This program succeeded in broadening the pool of experienced individuals that are accustomed to working in a research setting as well as make them into more critical thinkers, and that "the summer undergrad research participants will be more informed about the STEM field of study, and thus be more confidant in further proceeding with STEM as their preferred career choice" (student quote).

All research participants produced weekly reporting forms (verified by the PhD scientist), weekly Zoom video-conferencing meetings between the students and the researchers, and the PhD recorded these meetings. A Zoom mid-June meeting allowed each research team to display one PowerPoint slide as they described their project and progress. The practice presentations increased confidence and demonstrated research lessons learned.

The Survey of Undergraduate Research Experiences (SURE), a national survey for undergraduates who have recently completed a summer undergraduate research experience, was administered in an anonymous Qualtrics survey (Lopatto, 2004, 2009). Major survey findings of the five-week program indicate positive changes in the ability to think independently (16/17,94%), more intrinsic motivation to learn (16/17, 94%), better understanding of how scientists work on real problems (9/17, 53%), and increased self-confidence (12/17, 71%).

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