IN VIVO

The Publication of the Metropolitan Association of College and University Biologists

Fall 2018

Volume 40, Issue 1

51st ANNUAL MACUB CONFERENCE

Saturday, October 27, 2018

Queensborough Community College

The Art of the Neuron

Invited Speakers

Gregory Dunn, Ph.D.
Artist
and

Alison Dell, Ph.D.
Assistant Professor, St. Francis College

Instructions for Authors

IN VIVO is a peer-reviewed journal that is published three times yearly during the Fall, Winter, and Spring. Original research articles in the field of biology in addition to original articles of general interest to faculty and students may be submitted to the editor to be considered for publication. Manuscripts can be in the form of a) full length manuscripts, b) mini-reviews or c) short communications of particularly significant and timely information.

Articles can be submitted electronically to *invivo@mec.cuny.edu* or mailed as a printed copy (preferably with a diskette that contains the file) to the Editorial Board at Medgar Evers College. All submissions should be formatted double spaced with 1 inch margins. The title of the article, the full names of each author, their academic affiliations and addresses, and the name of the person to whom correspondence should be sent must be given. As a rule, full length articles should include a brief abstract and be divided into the following sections: introduction, materials and methods, results, discussion, acknowledgments and references. Reviews and short communications can be arranged differently. References should be identified in the text by using numerical superscripts in consecutive order. In the reference section, references should be arranged in the order that they appeared in the text using the following format: last name, initials., year of publication. title of article, journal volume number: page numbers. (eg. - [1]Hassan, M. and V. Herbert, 2000. Colon Cancer. *In Vivo* **32:** 3 - 8). For books the order should be last name, initial, year of publication, title of book in italics, publisher and city, and page number referred to. (eg. - Prosser, C.L., 1973. *Comparative Animal Physiology*, Saunders Co., Philadelphia, p 59.). Abbreviations and technical jargon should be avoided. Tables and figures should be submitted on separate

In Vivo (Brooklyn) is published by
The Metropolitan Association of College and University Biologists
Brooklyn, NY
url: https://macub.org/

In This Issue:

Register On-Line at MACUB.org

	Early Bird	In Advance	On Site
	By 9/21	**By 10/22**	**10/27**
Regular Membership & Conference	$55.00	$60.00	$75.00
Student Associate Membership & Conference	$40.00	$45.00	$60.00
Member's Spouse/Guest	$40.00	$45.00	$60.00

Call for Judges for 51st Annual Student Poster Presentation Competition

Over 100 college students will be presenting posters about their latest research projects within 11 biological disciplines. Volunteer judges are needed to provide constructive feedback to the community college, undergraduate, masters and graduate student presenters. We aim to provide each student with 3 judges to give feedback on their presentation. We hope you will take advantage of this opportunity to meet, support and encourage up and coming biologists by serving as a judge. If you are interested, please contact:

Poster Presentation Chair:
Email: UGolebiewska@qcc.cuny.edu

Poster Presentation Co-chair
Email: Mjavdan@qcc.cuny.edu

Welcome from Queensborough Community College

Queensborough Community College and the Department of Biological Sciences and Geology welcome the members and guests of the Metropolitan Association of College and University Biologists to the 51st annual conference.

Queensborough Community College of CUNY is one of the most diverse campuses in the nation and is a critical gateway into higher education for many students who are the first in their families to attend college. The College's students have roots in 127 countries and speak 78 languages. The College is committed to open-admission access for all learners and provides a comprehensive educational experience for 16,000 students through its 40 academic programs, a personalized advisement program and faculty-led research opportunities.

Faculty mentors integrate undergraduate research into the classroom, preparing students to present their scientific work at national and regional conferences. Among these conferences is the Annual Biomedical Research Conference for Minority Students (ABRCMS), Metropolitan Association of College and University Biologists (MACUB), CUNY Research Scholars Symposium, New York's American Chemical Society Undergraduate Research Symposium and Queensborough's Annual Honors Conference.

Many Queensborough students have won regional and national awards for their outstanding scientific presentations. Their long-standing records of winning regional and national awards at prestigious scientific conferences is an additional testament to the caliber of research that is possible at Queensborough. Course study is complemented by hands-on internships and field experiences with local partners such as the FDA, Stony Brook University, and Albert Einstein Medical College.

Faculty are very active in winning significant awards as well.

A $1,594,202 award from The National Institutes of Health (NIH) to provide an additional five years of funding (9/1/18-8/31/18) for the Bridges to the Baccalaureate Program that started at Queensborough in 2002. The program is a partnership between Queensborough, Queens College and The City College of New York to achieve the long-term goals of training and graduating under-represented (UR) science students, and to facilitate their transfer to baccalaureate programs in biomedicine or behavioral science.

Awards from PSC CUNY, C3IRG, Copper Development Association, Perkins, part of CUNY2020 and U.S. Department of Education MSEIP, total over $1.7 million. These grants help engage students in research and increase STEM retention and graduation.

Additional grant awards include: a 2015 Fulbright Academic and Professional Excellence Award; a 2016 breakthrough prize; a multi-year award of $371, 056 from the National Science Foundation for *Freshman Year to GeoScience Career*, a project that prepares the next generation workforce in the STEM disciplines, with a focus on increasing diversity in the geosciences; and award funds from CUNY for its Joint Seed Program, a new funding opportunity for CUNY to leverage relationships with the CUNY Advanced Science Research Center.

Also, Queensborough received a New York State Education award of $450,000 over five years for the STEP program; and a Hands-on Opportunities to Promote Engagement in Science award for lab supplies to support a collaborative program with students from Cardozo High School.

Once again, and on behalf of Queensborough Community College's Biological Sciences and Geology department, we welcome you to the annual MACUB conference.

Dr. Timothy G. Lynch
Interim President
Queensborough Community College

Dr. Nidhi Gadura
Professor and Chair
Queensborough Community College
Department of Biological Sciences and Geology

Understanding the Role of Motivation to Learn Science in Science and Non-Science Majors

Christina Mortellaro[1], Sophia Touri[1] and Genevieve Pinto Zipp[2]

[1]Saint Peter's University, Jersey City, NJ
[2]Seton Hall University, South Orange, NJ

Abstract

A common learning objective of core curricula in higher education and science educational programs specifically is to develop student's critical thinking skills via their development of scientific literacy. However, a consistent challenge in developing science literacy in the classroom is student's motivation to emerge themselves in the learning of "science". A mixed-method analysis of undergraduate students in introductory level biology courses was conducted to understand both STEM and non-STEM major's motivation to learn science. A concurrent triangulation design was utilized, with students completing both the Science Motivation Questionnaire (SMQ-II) and open-ended questions further exploring the topic of motivation to learn. Results from both the survey and open-ended responses identified that motivation to learn science is significantly different between STEM and non-STEM majors. The study findings offer support for the infusion of introductory biology courses designed specifically for STEM majors separate from introductory biology courses designed for non-STEM majors in order to provide each group with active learning experiences that capitalize upon, and promote student's level of motivation to learn science and seek to advance the development of their critical thinking skills.

Introduction

A common learning objective of many core curricula and science programs in higher education is to develop critical thinking skills via the development of scientific literacy in all students, both science and non-science majors. As a result, many introductory science courses in higher education are composed of both science and non-science majors. While developing students' critical thinking skills by requiring them to take science courses has become an important component of the undergraduate educational experience, the introductory science course is their only exposure to science in higher education while for the STEM majors; it lays the foundation for all future coursework and career preparation. Surprisingly, regardless of student's major, it is often found that students tend to lose their motivation to learn science thus posing a consistent challenge for educators in higher education to overcome[1]. In order to address these challenges and develop critical thinking skills in students in general, it is imperative that educators understand what positively and negatively affects students' levels of motivation to learn globally and specifically with regard to science. Additionally, by further understanding the motivation of science majors to learn science, higher education may gain insight that can assist in addressing the high attrition rates seen in the sciences[2]. Therefore, as educators it is important to understand students' motivation to learn science in an introductory science course as a means to improve critical thinking skills via the development of science literacy in both non- science and science majors and to improve the retention rates of science majors overall.

Motivation

According to Brophy, motivation to learn is "a student's tendency to find academic activities meaningful and worthwhile and to try to derive the intended academic benefits from them"[3]. In the literature, motivation has been identified as a major factor that can influence student learning[4]. In a report from the Higher Learning Commission, students identified motivation as a major reason for poor academic performance overall[5]. In a study conducted at a large, public university, Glynn *et al*.[1] found that motivation was related to students' college science grade point averages using the Science Motivation Questionnaire II (SMQ-II). Additionally, Glynn *et al*.[1] found that science majors scored higher on the SMQ-II than non-science majors. However, their results indicate that additional research in both science and non-science majors is necessary to improve retention in the sciences and learning outcomes. Therefore, the present study seeks to acquire a deeper understanding of both science and non-science majors motivation to learn science as it relates to their participation in an introductory science course, using a mixed method study design.

Active Learning

The process of becoming scientifically literate requires active learning by the student[6]. Widespread research has been conducted evaluating the gains of active learning experiences in the college classroom. It is now broadly accepted that active learning improves course outcomes across all disciplines, particularly in the science fields.[7-10]. As a result in higher education there has been a paradigm shift from the traditional didactic lectures in science courses to more student-centered instruction to promote active student engagement[7]. Faculty development opportunities in the University dedicate significant resources to support faculty endeavors in the classroom that promote active learning. However, faculty in higher education continue to observe students exhibit a lack of motivation as demonstrated by poor attendance, failing to complete assignments or activities, lack of participation in class activities and discussions and an overall lack of interest[4].

As a result, despite infusing diverse active learning strategies into science courses, improvement in academic performance, science literacy, has not been consistently observed. For example, Rutledge *et al.* conducted a study in an introductory biology course to determine the effect of utilizing active learning experiences on course grades[11]. The study revealed the use of active learning exercises resulted in 2.6 points increase in course averages. However, Rutledge *et al*. suggested if students were motivated to participate in *all* exercises, averages could have increased by 5.2 points.

In order for students to benefit from an active learning approach to education, their motivation to learn is key. As students' motivation to learn increases, their engagement in active learning experiences will improve, ultimately leading to an increase in academic performance, decision making, and science literacy. Therefore, the purpose of this study is to understand both science and non-science student's motivation to learn science in an introductory biology course using a mixed method study design. By further understanding student's motivation to learn science, educators would be better equipped to develop active learning strategies that may impact both science and non-science student's science literacy and their decision making skills.

Methodology

Instrumentation

The Science Motivation Questionnaire (SMQ-II) is a valid and reliable questionnaire to assess components of students' motivation to learn science in college and high school courses[1]. It is a 25- item questionnaire using a Likert scale with readability at the sixth-grade level. The questionnaire includes five ordinal scales, each with five items: intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation. The items are presented on the questionnaire without identifying to which scale the item is referring. The items are scored from (0) never to (4) always, with the overall score range from 0-20. According to Glynn *et al.*[1], the reliabilities of each of the five scales as measured by Cronbach's alpha are: Intrinsic motivation (0.89), self-determination (0.88), self-efficacy (0.83), career motivation (0.92), and grade motivation (0.81). The internal consistency for all 25 items is 0.92, indicating strong reliability.

In addition to the SMQ-II, the questionnaires provided to participants also included a demographic profile developed by the primary investigator (PI) to identify demographic information in the form of closed ended questions for educational level, previous education, major area of study, employment, as well as open ended questions, which further explored motivation and its perceived impact on learning. The electronic form of the survey was developed via Google Forms. The Google form included a reproduced copy of the SMQ-II © 2011 Shawn M. Glynn, and PI developed demographic and open ended questions (Figure 1).

Setting & Sample

This study consisted of a convenience sample of undergraduate students who voluntarily participated in the study. The participants of the study were enrolled in an introductory biology course at a private, liberal arts university. Participation and completion of the surveys were completed electronically at a place and time of convenience. The study was approved by the Institutional Review Board.

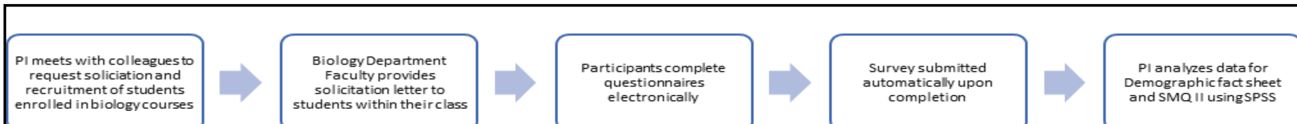

Figure 1: Sequence of data collection

Protocol

Faculty members of the Biology Department were asked by the PI to distribute a paper or email version of the letter of solicitation/ informed consent form to all students enrolled in their respective course(s). Students interested in voluntarily participating in completing the anonymous surveys accessed the survey through the link provided in the solicitation letter.

Analysis

A concurrent triangulation mixed methods design was used, also known as a convergent parallel design, which is a "type of design in which qualitative and quantitative data are collected in parallel, analyzed separately, and then merged"[12]. A variation of the convergent design, referred to as data-validation was used, and includes the "use of both open and closed ended questions and uses the results from the open- ended questions to better understand the result of the closed ended questions"[12].

Based on the triangulation design model, both types of data were analyzed independently and concurrently. Nonparametric statistics were used as the SMQ II measures motivation on are ordinal scales[13]. For all the statistics analyses, significant differences will be fixed at 0.05 level and 0.2 β level with a corresponding power of 80%.

For qualitative data analysis, the PI developed *a priori* codes based upon the literature. To code qualitative data, text from open-ended question responses were extrapolated into small units or phrases, and labels were assigned to each unit that corresponded to the *a priori* codes. During the coding process, *in vivo* codes (labels from exact words or phrases of the participants) were used to establish additional codes. Data was further transformed to account for the number of occurrences of each code (theme). Inter-coder agreement of 80% for each code established was reached between the PI and an independent coder experienced in qualitative analysis protocols and procedures and the topic of motivation.

Results

Demographics

The study sample consisted of 77 undergraduate students enrolled in introductory biology courses at one private, liberal arts university. The sample consisted of 56% STEM majors and 44% non-STEM majors with 23.4% first year students, 23.4% second year students, 26.0% third year students, and 27.2% fourth year students.

Based on the results of the SMQ-II, all students enrolled in the introductory biology course had an overall motivation score of 78.03 out of 100 possible points with a standard deviation of 16.04. The motivation subscales were each scored out of 20 possible points: intrinsic motivation 14.68 (s.d. 4.77), self- efficacy 15.30 (s.d. 3.27), self-determination 14.82 (s.d. 3.89), grade motivation 18.04 (s.d. 2.44), and career motivation 15.19 (s.d.5.43). When evaluating possible associations between the overall motivation score of undergraduate students enrolled in an introductory biology course, a significant, moderate relationship between overall motivation score and major, $r_s = -0.48$, $p < 0.05$ was observed.

Quantitative

Using non-parametric comparison of means (Mann-Whitney U), a significant difference was found in the overall motivation score and all five motivation subscales (Table 1) between STEM majors and non-STEM majors enrolled in an introductory biology course. (Figure 2).

A significant difference was also observed in the overall motivation score, self determination, and grade motivation between students (Table 2) that studied less 5 hours per week and more than 5 hours per week. (Figure 3)

A significant difference was also observed between STEM and non-STEM students and the number of hours per week dedicated to studying ($U=476.00$, $p=0.005$) with STEM majors studying for their biology course for more than five hours per week as compared to non-STEM majors. Using a non-parametric comparison of means (Kruskall Wallis), no significant difference was found in the overall motivation scores of students who work 5-10 hours per week, 11-15 hours per week, 16-20 hours per week, more than 20 hours per week, and student who do not work.

In the final quantitative question of the survey, participants were asked to identify "all" instructional methods in which they participated in during their current biology course from a list provided on the questionnaire. The author coded these as either didactic/ teacher centered learning methods or active/ student centered learning methods. Responses from the participants indicated that 16.8% partook in various teacher centered, passive learning techniques, and 83.2% participated in both teacher centered, passive learning techniques and student centered, active learning techniques.

Qualitative

Several open-ended questions were included as part of the studies demographic questionnaire and were analyzed qualitatively. The first open-ended question asked students to, "describe their motivation to learn by identifying activities or experiences that enhance their motivation to learn". The PI generated predetermined themes based on the subscales of the SMQ-II to explore and code the student's responses to this question. During the coding process, an additional theme emerged regarding the impact of family on student motivation to learn science. (Table 3).

Upon further reflection of the student responses to this question a true interest in science was evident. For example, one student replied, "Hearing of new scientific discoveries is like my drive, I want to know more." Others recognized the significance of science to their lives such as, "the world we live in motivates me to learn, because it draws me to want to know how everything on Earth came about and how humans effect our Earth," and "the world and people in it is always changing so biology helps you learn to analyze these new findings."

A second open-ended question asked students to identify factors that may impede or hinder them from learning science or diminish their motivation to learn science. Again, predetermined themes were formed based on the literature such as distractions and challenging content. Similar to the first question, additional themes emerged during the coding process and therefore, *in vivo* coding was again used and identified themes such as the course instruction or teaching style, personal insecurities, "too much work at once," and nothing." (Table 4).

The distractions reported included friends, social media, cell phones, and video games. Student insecurities also emerged in the responses, "My insecurities sometimes prevent me from

Table 1	STEM	Non-STEM	U	Sign.
Intrinsic	15.86 (4.36)	13.18 (4.90)	477.00	0.009*
Self- efficacy	16.02 (2.96)	14.38 (3.46)	510.00	0.023*
Self determination	16.07 (3.48)	13.24 (3.85)	408.50	0.001*
Career motivation	17.26 (3.85)	12.59 (6.04)	354.5	0.000*
Grade motivation	18.91 (1.54)	16.94 (2.91)	442.50	0.002*
Total SMQ	84.12 (12.63)	70.32 (16.74)	348.50	0.000*

Table 1: A comparison of means of each of the five SMQ-II sub scales and overall score between Science and non-science majors. * indicates a significant difference was observed.

Table 2	< 5 hr./week	>5 hr./ week	U	Sign.
Intrinsic	14.18 (4.97)	16.73 (3.17)	322.50	0.065
Self efficacy	14.98 (3.45)	16.60 (2.06)	348.00	0.130
Self determination	14.19 (3.86)	17.40 (2.90)	227.00	0.002*
Career motivation	14.73 (5.43)	17.13 (5.14)	314.50	0.050
Grade motivation	17.73 (2.57)	19.33 (1.18)	268.50	0.009*
Total SMQ	75.81 (16.17)	87.20 (12.04)	251.50	0.006*

Table 2: A comparison of means of each of the five SMQ-II sub scales and overall score between students that study less than 5 hours per week and students that study more than 5 hours per week. * indicates a significant difference was observed.

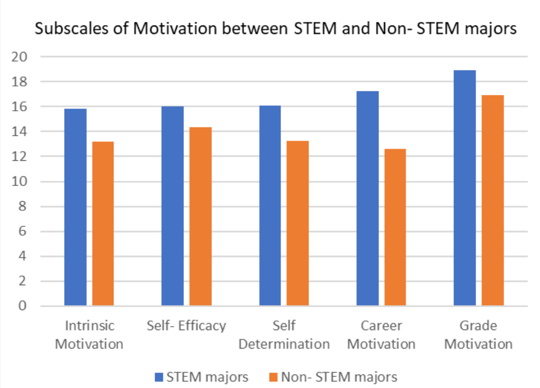

Fig. 2: SMQ-II subscale scores between STEM and Non-STEM majors

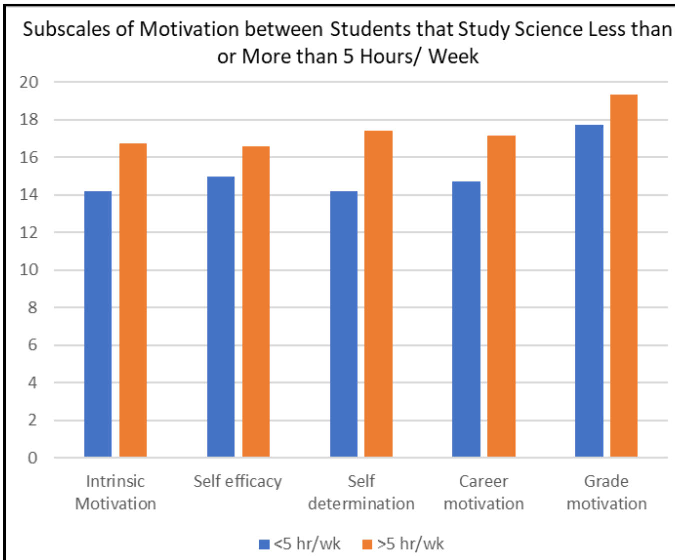

Fig. 3 SMQ-II subscale scores between students that study science less than or more than five hours per week.

A-Priori Theme	Response %
Intrinsic Motivation	46.9%
Self-Efficacy	10.9%
Self Determination	6.3%
Career Motivation	9.4%
Grade Motivation	17.2%
Emerged Theme	
"Family"	9.4%

Table 3: Participant response percentage of predetermined and emergent themes to "identify activities or experiences that enhance motivation to learn."

A-Priori Theme	Response %
Distractions	28.4%
Uninteresting or Difficult content	10.4%
Teaching style	16.4%
Emerged Theme	
Workload	11.9%
Insecurities	10.4%
Nothing	22.4%

Table 4: Participant response percentage of predetermined and emergent themes to "identify factors that may diminish motivation to learn science."

learning…. Often times, the insecurities are me wondering if I am good enough or me comparing myself to my peers." It was also surprising to see a number of students report, "Nothing prevents me from learning," although some expanded on the statement such as, "Nothing hinders me from learning. Learning is something that one chooses to do. One has to want to learn, wants to be interested, wants to understand."

Discussion and Conclusion

In this study, undergraduate students enrolled in introductory biology courses exhibited similar motivation scores to previously conducted studies by Glynn *et al*.[1]. Based on these previous studies, the significant differences in all of the motivation scales between STEM majors and non-STEM majors in this study were not surprising. While establishing construct validity of the SMQ-II, Glynn and colleagues[1] evaluated the motivation to learn science in science and non-science majors in core curriculum science classes. They also observed higher scores of all motivational subscales in science majors than non- science majors. Additionally, the present study observed grade motivation as the highest motivational construct of the subscales for both STEM and non-STEM majors further supporting the findings of Chumbley, Haynes, and Stofer[14] and Glynn *et al*[1].

Grade motivation was also the highest of the subscales in students that reported studying less than five hours per week and students studying more than five hours per week. One would assume that if Grade motivation was high, students would generally dedicate more time to studying to earn a higher grade. However, the results of this study do indicate that there is a significant difference in grade motivation of students studying less than five hours per week and students studying more than five hours per week. STEM majors also studied for their biology course more than non- STEM majors. Motivation to earn a good grade in a course does not necessarily indicate a students' motivation to learn science; grades do not indicate long term-learning or the ability to think critically[14]. Although grades are good motivators of short-term goals and college success, grade as motivation does not promote life-long learning or developing science literacy. For long term, meaningful learning to occur, student engagement is necessary[15].

The majority of students in the present study reported experiencing active learning in their biology classroom. The literature suggests that active learning strategies improve student outcomes and student motivation to engage in learning activities[7,16]. Despite these active learning strategies in the science classroom, non-science majors still demonstrated lower levels of motivation compared to science majors which could potential lead to low levels of achievement in the science course. As Jin and Bierma discuss, science literacy development may occur differently in STEM and non-STEM majors and may require different educational approaches[17]. Therefore, the active learning strategies preferred by STEM and non-STEM majors may differ as well. In these introductory science courses, even though active learning methodologies are being employed, the active learning strategies that would promote motivation and learning in STEM majors may be different than the active learning strategies that would promote motivation and engagement in non-STEM majors. For that reason, having both STEM and non-STEM majors in the same introductory science course, the active learning is not promoting their motivation to learn.

The qualitative data provided greater insight into understanding what motivates students to learn science. Interestingly, the majority of responses identified an intrinsic motivation to learn contrary to the results of the quantitative results in the scores of the SMQ-II. To enhance motivation, educators can tap into this intrinsic motivation by linking it to their end goal (career), but more importantly develop more meaningful, life- long learning. Even if their career goals are not in the STEM fields, we still want to improve their motivation to learn science to focus on the development of their critical thinking skills and scientific literacy.

The results obtained from this mixed method research design support previously observed differences in motivation levels between science and non-science students in an introductory level biology course. Given the observation further supported in this study that motivation to learn science is significantly different between STEM and non- STEM majors, we believe that designing separate introductory biology courses specifically for STEM majors and non-STEM majors is warranted. By designing separate introductory science courses, educators can more effectively and efficiently provide each group with active learning experiences that capitalize upon and further promote their motivation to learn science, and develop science literacy and critical thinking skills. To further explore this notion, future work should look at each group independently within a course that has been designed to use the motivation they have and advance it through meaningful, active learning experiences that would enhance engagement, critical thinking and support their career goals.

References

[1]Glynn, S.M., P. Brickman, N. Armstrong and G. Taasoobshirazi, 2011. Science motivation questionnaire II: Validation with science majors and non science majors. Journal of Research in Science Teaching **48(10):** 1159-1176.

[2]President's Council of Advisors on Science and Technology, 2012. Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Washington D.C.: U.S. Government Office of Science and Technology.

[3]Brophy, J., 2010. Motivating students to learn (3 ed.) (p.205-206). New York: Taylor & Francis.

[4]Williams, K. and C. Williams, 2011. Five key ingredients for improving motivation. Research in Higher Education Journal **11:** 1-23.

[5]Cherif, A., F. Movahedzadeh, G. Adams and J. Dunning, 2013. Why do students fail? A collection of papers on self-study and institutional improvement, The Higher Learning Commission pp 25-51.

[6]Gormally, C., P. Brickman, B. Hallar and N. Armstrong, 2009. Effects of inquiry- based learning on students' science literacy skills & confidence. International Journal for the Scholarship of Teaching & Learning **3(2):** 1-22.

[7]Freeman, S., S.L. Eddy, M. McDonough, M.K. Smith, N. Okoroafor, H. Jordt and M.P. Wenderoth, 2014. Active learning increases student performance in science, engineering, and mathematics. Proc. Natl. Acad. Sci. **111:** 8410-8415.

[8]Cavanagh, A.J., O.R. Aragon, X. Chen, B.A. Couch, M.F. Burham, A. Bobrownicki and M.J. Graham, 2016. Student buy-in to active learning in a college science course. CBE-Life Sciences Education **15(ar76):** 1-9.

[9]Haak, D., J. HilleRisLambers, E. Pitre and S. Freeman, 2011. Increased structure and active learning reduce the achievement gap in introductory biology. Science **332:** 1213-1216.

[10]Deslauriers, L., E. Schelew and C. Wieman, 2011. Improved learning in a large enrollment physics class. Science **332(6031):** 862-864.

[11]Rutledge, M.L., J.W. Bonner and S.S. Lampley, 2015. The impact of active learning exercises on the grade distribution in a large lecture, general education biology course. Journal of College Science Teaching **44(5):** 16-25.

[12]Creswell, J.W. and V.L. Clark, 2011. Designing and Conducting Mixed Methods Research (2nd ed.). Thousand Oaks, CA: Sage Publications.

[13]Portney, L.G. M.P. Watkins, 2015. Foundations of Clinical Research: Applications to Practice (3rd ed.). Philadelphia, PA: F.A. Davis Company.

[14]Chumbley, S.B., J.C. Haynes and K.A. Stofer, 2015. A measure of students' motivation to learn science through agricultural STEM emphasis. Journal of Agricultural Education **56(4):**107-122.

[15]Sinatra, G.M., B.C. Heddy and D. Lombardi, 2015. The challenges of defining and measuring student engagement in science Educational Psychologist **50(1):** 1-13.

[16]Cudney, E.A. and J.M. Ezzell, 2017. Evaluating the impact of teaching method on student motivation Journal of STEM Education **18(1):** 32-49.

[17]Jin, G. and T. Bierma, 2013. STEM for non-STEM majors: Enhancing science literacy in large classes. Journal of College Science Teaching **42(6):** 20-26.

An Assessment of Maximizing Carbon Sequestration Potential of *Eucalyptus* by Species

Brandy Garrett Kluthe[1*], Mourad Ben Hassine Ben Ali[2] and Steven L. Stephenson[2]

[1]Saint Peter's University, Jersey City, NJ and
[2]University of Arkansas, Fayetteville, AR
***Corresponding author: brandygarrettkluthe@gmail.com**

Abstract

Eucalyptus plantations are abundant across Kenya and other parts of the world. These trees are rotationally harvested after several years of growth. This study aimed to determine if an optimal harvest age could be determined to maximize carbon content for each species of *Eucalyptus,* thus aiding in carbon sequestration in the region. Tree core samples were taken from several species of *Eucalyptus* at a variety of ages. These samples were then used to calculate, by using a density determining method, the measure of the total carbon in each tree. The results were organized by age and species of each of the trees sampled and a mean density was determined. The results indicated that there is variation in the total carbon content of the various species. This variation was also different by age. This could lead to an optimal harvest age by species that can maximize carbon sequestration potential of a *Eucalyptus* plantation.

Introduction

Carbon dioxide emissions from the combustion of fossil fuels are a large contributor to increasing CO_2 concentrations in the atmosphere. This rise in atmospheric CO_2 has been linked to global climate change as a direct result of anthropogenic actions[1]. In addition, the sea level has risen 15-23 cm during the last century. Ecosystem shifts, increases in drought and wild fires and loss of sea ice are being attributed to increased CO_2 levels in the atmosphere[2]. Fossil fuels are not the only contributor to CO_2 emissions since changing land use constitutes approximately thirty-three percent of the carbon released into the atmosphere. This comes primarily from the expansion of agriculture in tropical regions. Tropical ecosystems contain huge reserves of carbon trapped in the organic material produced within them[1]. It is estimated that tropical deforestation is already contributing approximately 1.5 billion tons of carbon to the atmosphere each year[3]. Concern over carbon dioxide levels in the atmosphere has led to expanded research on possible methods for trapping this gas and thus reducing these levels. Methods for trapping atmospheric carbon include abiotic sequestration and biotic sequestration. In the biotic sequestration methods, afforestation presents some feasible possibilities to capturing carbon. Restoration of tropical forests and better tree management practices may serve as an important carbon pool in the future[2]. Several studies have examined the carbon sequestering potential of trees. Carbon sequestration refers to the removal of atmospheric carbon and trapping it in a pool in which it can be stored for a period of time[4]. Photosynthesizing organisms remove the carbon from the atmosphere and transfer it into tissues and organic molecules for later use. The carbon is maintained in the organism even after it dies. The decaying organic matter is available for other organisms to break down and eventually will be recycled or become part of the soil carbon pool[5].

Eucalyptus trees in Kenya were selected for this study due to the availability of large woodlots in which to establish study plots. It grows rapidly, which unquestionably results in superior carbon sequestration potential. As an introduced species, it has already been used extensively in the country to provide a wood source for construction and other practices. *Eucalyptus* trees can be found in a variety of settings throughout Kenya. Species belonging to this genus are the predominant trees planted throughout Kenya due to their rapid growth and ability to survive in marginal environments[6]. Its use for fuelwood and timber products as well as its fast maturation time has contributed to an increased abundance. Tea plantations in the western highlands depend on the *Eucalyptus* as a wood source for drying the fresh tea leaves. It can now be found on even the smallest farming plots. In addition to *Eucalyptus* being abundant in the country, the plots are planted with equal spacing making them ideal for estimating carbon content in woodlots as opposed to the more natural and biodiverse native forests.

There are six pools that can be measured in Land Use, Land-Use Change and Forestry (LULUCF) activities. For this study, the above ground tree pool was used. This is the pool that accounts for the largest percentage of sequestered carbon in a forest system[1]. The root mass was not estimated because it has the potential to grow new sprouts after the tree has been cut. This is a practice that is commonly used and can continue to serve as a carbon pool after the tree has been harvested. Coarse woody debris (CWD) is sometimes used to assess a component of the carbon content in a forest ecosystem but was not calculated in this study. Cultural practices in the area prevent CWD from staying on the ground very long because it is generally collected and used as firewood.

In order to calculate the carbon content in a woodlot it is necessary to determine the biomass of the tree; for this study just the above ground biomass (AGB) of representative trees in the woodlot was used. This can be obtained in different ways that can affect the accuracy of the results[7]. For example, calculations can be applied that use site sampled data and published densities for specific species of trees. These are based on regression equations that were derived from harvested trees in specific regions and by specific tree species. Density of *Eucalyptus maculata* was established using this method in New South Wales with a resulting density of 0.583 g/cm^3 reported[8]. Differences in temperature, elevation and annual rainfall could influence the density from one region to another. Githiomi and Kariuki reported a range from 0.414 g/cm^3 to 0.517 g/cm^3 in various aged *E. grandis* in Kenya[9]. For the purpose of this study, the density for each tree measured was calculated from tree core samples obtained at each sample site. The more information that can be obtained, the greater the accuracy of the calculations, and the more accurate value for the amount of carbon contained within the woodlot.

Materials and Methods

Tree core data

Only species of *Eucalyptus* were measured and recorded. These included *E. grandis, E. saligna, E. maculata, E. globulous* and hybrid *E.* trees. Tree core samples were taken from 38 sites in Kenya (Figure 1) with a Swedish increment borer (Figure 2A). The core from each tree was packaged, labeled and shipped back to the University of Arkansas for later analysis.

Sampling sites were selected based on availability. Sites were in predominately large *Eucalyptus* plantations. The individual trees selected were chosen visually to ensure that they exhibited good health and were representative of the overall woodlot. The selected tree at each site was measured for diameter at breast height (DBH) and also for the height of the tree. This was done by measuring out 25 meters from the base of the tree. From this point a measurement was taken looking through a clinometer to the top of the tree. If the ground was level then the angle for the height of the tree was obtained. This could be used to calculate the tree height which was later used to calculate the carbon content of the tree. Wood cores were taken at the DBH level. Intact cores were stored in plastic straws that were slit for ventilation, labeled and shipped to the University of Arkansas. Upon arrival, they were placed in a -20°C freezer.

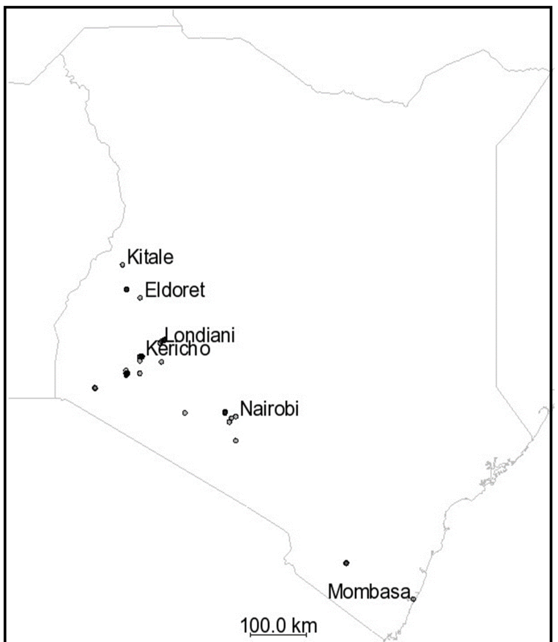

Figure 1. Localities in Kenya where *Eucalyptus* tree cores were collected.

The samples were removed from the freezer when measurements were taken. They were allowed to completely thaw. Each length and diameter of each sample were measured and recorded while viewing under a stereoscope for accuracy. This step was done to validate measurements obtained from the water displacement method. Each sample was then placed in labeled weigh boats and left to soak for one hour (Figure 2B). The samples were then measured for volume using the water displacement method[10]. This is done by placing a container of water on a scale. The next step was to zero out the scale then place the sample in the water. The sample was gently pushed under the water with a small needle (Figure 2C). The recording on the scale gave the weight of the sample which is also equivalent to the volume of a particular sample. This can be cross checked against the previous measurements and may be helpful when the samples have multiple pieces. The water displacement method should be more accurate, especially when the samples are irregular in shape. Once the samples were weighed to generate the volume, they were then returned to their labeled weigh boat and placed in an oven dryer for 72 hours to remove all the moisture. Samples were then reweighed to obtain the oven dry weight. The density of each sample was then calculated as D (density) = M (mass)/V (volume). These values were then recorded for later use in calculating carbon content (Table 1).

For calculating the amount of AGB in Kenya's *Eucalyptus* woodlots, an equation based on allometric regression models was used. The specific formula was selected based on the work of Chave *et al*., 2005[11]. The authors used tropical tree harvest data from the last several decades and compared it with published regression models to see which one was the most accurate in tropical forest woodlots. The formula where ρ is the wood density in (g/cm³), D is the diameter at breast height in (cm) of the sampled tree and H is the height in (m) of the tree.

$$\mathbf{AGB\ (est) = \exp(-2.977 + \ln(\rho D^2 H)) \equiv 0.0509 \times \rho D^2 H}$$

After the biomass was calculated for each sample, the carbon content could be determined. To determine the carbon content, the biomass is multiplied by 0.5 (Table 1). This is the recommendation from the Intergovernmental Panel on Climate Change's guide to good practice guidance for land use, land-use change and forestry[12]. Table 1 also includes the species of tree and age of the tree, if known. This was gathered from the woodlot manager or owner of the woodlot. When a sample species was unknown, it was recorded as a mixed species. If the age of the tree was unknown, it was recorded as unknown.

Figure 2. *Eucalyptus* core sampling method using an increment borer. B Individual tree core samples in weigh boats. C water displacement method. Photographs by Brandy Garrett Kluthe, 2014.

Results

Calculations to determine the density of the sampled trees were carried out. This resulted in a density value for each species of tree as well as a density value for several different ages for each species sampled (Table 2). With the exception of *E. grandis*, all species had a small sample size and the trees did not span a large range in ages. The average density for each species was determined. The average density of all combined samples was 0.4545 g/cm³. The density determinations can be used to calculate the above ground biomass and total carbon content of individual trees as well as entire woodlots. This is possible if the acreage of the woodlot is known as well as the spacing of the trees. For example, if one hectare of *Eucalyptus* is planted with a 3 meter spacing there would be approximately 1,111 trees in that woodlot. A representative tree similar to the other trees in the woodlot could be measured for DBH and height. Based on a density of 0.4545 g/cm³, the established formula could be applied to calculate the entire biomass of the woodlot. If the DBH is 25

Table 1. Final density value and carbon total for each sample based on oven dry weights and water displacement volume measurements. The table includes the age and species of tree.							
Sample site	**vol (g/ ml3)**	**dry weight g**	**density g/ cm3**	**age**	**Species**	**AGB kg**	**Carbon Content kg**
Kefri-1-2014	0.73	0.27	0.369863014	7	mixed	87.82131118	43.91065559
Kefri-2-2014	0.58	0.23	0.396551724	7	mixed	99.56776049	49.78388025
Kefri-3-2014	1.15	0.47	0.408695652	2	*E. grandis*	8.888072665	4.444036333
kefri-4-2014	0.87	0.41	0.471264368	11	*E. saligna*	291.8372077	145.9186039
Kefri-5-2014	0.6	0.23	0.383333333	11	*E. Saligna*	467.6887263	233.8443631
Kefri-6-2014	0.76	0.42	0.552631579	9	*E. saligna*	512.8364454	256.4182227
Fin-1-2014	1.02	0.36	0.352941176	4	*E. grandis*	74.18489185	37.09244593
Fin-2-2014	0.3	0.1	0.333333333	3	*E. grandis*	91.274898	45.637449
Fin-3-2014	0.43	0.15	0.348837209	6	*E. grandis*	159.8031352	79.90156762
Fin-4-2014	0.4	0.15	0.375	5	*E. grandis*	91.78784784	45.89392392
Fin-5-2014	0.79	0.36	0.455696203	7	*E. grandis*	401.8617467	200.9308733
Fin-6-2014	0.49	0.22	0.448979592	9	*E. grandis*	186.3772633	93.18863163
Lond-1-2014	0.34	0.2	0.588235294	10	*E. globulus*	106.9190429	53.45952147
Lond-2-2014	0.64	0.32	0.5	10	*E. globulus*	449.6751745	224.8375873
Lond-3-2014	0.56	0.25	0.446428571	10	*E. grandis*	430.5673992	215.2836996
Lond-4-2014	0.78	0.34	0.435897436	11	*E. grandis*	272.3841128	136.1920564
Lond-5-2014	0.58	0.32	0.551724138	12	*E. grandis*	920.5472728	460.2736364

Table 2. Measured density means of each *Eucalyptus* tree core sample organized by species and age.			
E. grandis		**Other species**	
age (years)	density (g/ cm³)	age (years)	density (g/cm³)
2	0.44	7	0.38
3	0.33	9	0.55
4	0.35	10	0.51
5	0.39	11	0.44
6	0.35		
7	0.46		
8	0.37		
9	0.45		
10	0.37		
11	0.49		
12	0.51		
13	0.41		
16	0.43		
combined ages	0.41	combined ages	0.46

cm and the tree height is 46 m then the calculated biomass of the tree is approximately 665 kg with the carbon content calculated at approximately 332 kg. This could then be applied to the entire woodlot by multiplying the calculated number by the number of trees. For the example, the one hectare woodlot would contain approximately 368,852 kg of carbon stored within the trees in an even-aged woodlot. Species and age specific calculations can increase the accuracy of the total carbon content in the selected woodlots. Regional information can also help assess the carbon content in an area. In the majority of Kenya's tea plantations, most trees are not older than 10 years of age, with the average country-wide harvest age between 8-12 years[13]. This gives a general age for determining size of the trees over a large area of Kenya in order to calculate total carbon content held in *Eucalyptus* forests.

Discussion

Density can be calculated form tree core samples. The density data, along with DBH and tree height can be applied using the formula described by Chave *et al.* to determine the above ground biomass of a tree[11]. This can then be used to calculate the total carbon content in a tree. Using the data collected from several species of *Eucalyptus* with varying ages, a total carbon content of large expanses of woodlots can be determined. Kenya has approximately 100,000 ha of *Eucalyptus* forests[13]. With a conservative estimate of the trees being eight years of age, the total carbon pool in *Eucalyptus* forests in Kenya would be estimated at 36,978,825,906 kg.

With the larger sample size of *E. grandis*, a general trend towards a higher density with age is apparent (Table. 2). This is consistent with the research by Githiomi and Kariuki who studied the density of *E. grandis* in the central Rift Valley of Kenya. They found that the density of the tree increased with age and height with the highest density at 10 years of age[9]. This would indicate that to maximize the carbon capture of a tree, harvest should be at 10 years of age. Further sampling in the other *Eucalyptus* species could also reveal an optimal harvest age based on calculated density. Kenya's *Eucalyptus* trees are grown predominately for commercial purposes. The harvested trees are used for transmission poles, construction and as a fuel source for drying tea leaves. Trees that are cut still hold the carbon they accumulated during growth. That carbon in trapped until the tree begins to decay or is burned. The trees that are burned will release carbon but not all of it. In the large commercial plantations where *Eucalyptus* are grown as a fuel source for drying tea leaves, the tree stumps are allowed to regrow the trees. This occurs on a three time rotation before the tree roots are removed and new seedlings are planted. During growth the tree is contributing to root development which also traps and stores carbon.

As a well-established tree in the country, the *Eucalyptus* tree also serves as a source of income for farmers who incorporate small woodlots on their land. The duel benefit of providing work and an income for rural farmers with the carbon sequestration ability of the *Eucalyptus*, make it a feasible possibility as an established carbon pool[1].

References

[1]Kongsager, R., J. Napier and O. Mertz, 2013. The carbon sequestration potential of tree crop plantations. Mitigation and Adaptation Strategies for Global Change **18:** 1197-1213.

[2]Lal, R., 2008. Carbon sequestration. Philosophical Transactions of the Royal Society B: Biological Sciences **363:** 815 -830.

[3]Solomon, S.D., M. Qin, Z. Manning, M. Chen, K.B. Marquis, M. Averyt, M. Tignor and H.L. Miller, 2007. Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

[4]Lal, R., 2004. Soil Carbon Sequestration Impacts on global climate change and food security. Science **304:** 1623-1627.

[5]Roxburgh, S.H., S.W. Wood, B.G. Mackey, G. Woldendorp and P. Gibbons, 2006. Assessing the carbon sequestration potential of managed forests: a case study from temperate Australia. Journal of Applied Ecology **43**: 1149-1159.

[6]Dessie, G. and T. Erkossa, 2011. Eucalyptus in East Africa Socio-economic and environmental issues. Forestry Department and Agriculture Organization of the United Nations. Working Paper FP46/E.

[7]Brown, S., A.J.R. Gillespie and A.E. Lugo, 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science **35**: 881-902.

[8]Ash, J. and C. Helman, 1990. Floristics and vegetation biomass of a forest catchment, Kioloa, south coastal New South Wales. Cunninghamia **2:** 167-182.

[9]Githiomi, J.K. and J.G. Kariuki, 2010. Wood basic density of *Eucalyputus granids* from plantation in central Rift Valley, Kenay: Variation with age, height level and between sapwood and heartwood. Journal of Tropical Forest Science **22:** 281-286.

[10]Chave, J., 2005. Measuring wood density for tropical forest tree. A field manual for the CTFS sites. http://chave.ups-tlse.fr/chave/wood-density-protocol.pdf.

[11]Chave, J., C. Andalo, S. Brown, M.A. Cairns, J.Q. Chambers, *et al.,* 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99.

[12]Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger *et al.,* 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Intergovernmental Panel on Climate Change, Japan.

[13]Oballa, P.O., P.K.A. Konuche, M.N. Muchira and B.N. Kigomo, 2010. Facts on Growing and Use of Eucalyptus in Kenya. Kenya Forestry Research Institute, Nairobi, Kenya.

.

Reaffirming the Power of Nature's Pharmacy through Pharmacognosy

Kumkum Prabhakar

Nassau Community College, Garden City, NY

Abstract

Ethnobotany can be used as a pathway for undergraduates to gain interest in botany, which is almost going extinct. Humans have used plants for healing purposes for centuries and presently there is a trend to blend conventional medicines with the complimentary ones. Numerous traditional medicines are going through scientific investigations and Pharmacognosy is involving researchers and practitioners to test claims made for centuries. Ancient humans recognized the healing power of plants in various cultures and that knowledge survived as it moved from one generation to another. Numerous studies confirm that medicines used in conventional system are directly derived from natural sources (mainly plants) or are analog thereof. Understanding medicinal power of phytochemicals used in different cultures and their mode of action can provide evidence-based preventive system of healthcare for all. This review also includes discussion on how to engage undergraduate students in testing antimicrobial properties of plant products or solving taxonomical/ecological issues based on the type of secondary metabolites. Knowledge of phytochemicals in different members of the same family or in plants from different families can be used in molecular biology or bioinformatics to study phylogenetic relationships.

Key Words: bioactive; ethnobotany; medical botany; pharmacognosy;

Recognizing Healing Power of Nature

Early humans must have recognized the therapeutic power of plants and other natural resources since the Neolithic period, about 8,000-5,500 BC, when they shifted from food-gathering to food-producing practices. It is certainly difficult to interpret initial practices as magic and religion also played a significant role in the healing processes. Probably, food gathering practices and reasoning ability helped to apply "Doctrine of Signature" in recognizing medicinal herbs. Paracelsus, being the strongest proponent of the doctrine of signatures, believed that herbs resembling various parts of the body can be used by herbalists to treat ailments of those body parts. A theological justification, as stated by botanists at that time, was that God would have wanted to show men what plants would be useful for. Bennett[1] critically reviewed the concept of Doctrine of Signatures to conclude it as an important mnemonic device of great importance in ancient cultures. Another possibility is that it might have been simple trial and error and passing of traditions from one generation to another as it still happens in India and other countries. Observing animals and their behavior might have also helped in selecting the treatments of some ailments. Most of the information of prehistorical medicine is based on paleontology, anthropology, and cave art, thus providing only circumstantial evidence as a result. It certainly reveals the extraordinary intelligence of ancient humans in being able to recognize natural sources of medicinal value.

Documentation of Medical Practices

Jackson[2] in "A Global History of Medicine," a collection of practices in medicines from different continents, mentions that scholars and translators from China, Tibet, Kashmir, India, Europe, and Arabia congregated, around 13th and 14th centuries, at the court of Judeo-Muslim scholar and Vizier Rashid al-Din. It is further reported that exchange among scholars led to the documentation of medical knowledge. This documented literature is only now being studied in the light of its significance for cross-cultural transmission.

Artifacts about the cause and progress of illnesses from the Shang Dynasty, traditional dates: 1766-1122 BCE, Hang dynasty, 202 BCE-220 CE, and through various stages of evolution, including involvement with religious organizations to modern Traditional Chinese Medicines, provide a meaningful integration of Western and Eastern treatments[3]. During my visit to China, I had the opportunity to observe many practitioners of Chinese medicine and the use of different natural products not only of plant origin but also many animals' parts and skins.

Ayurveda, an Indian ancient holistic approach known for thousands of years, includes physical and biological perspectives in its philosophy. By 400 AD, Ayurveda works were translated into Chinese and scholars from China are reported to be studying medicine in India at Nalanda University by 700 AD (http://www.healthandhealingny.org/tradition_healing/ayurveda-history.html). The origin of Ayurveda is attributed to Atharva Veda where mention is made of several diseases with their treatments. Later, from the 6th Century BC to 7th Century AD, there was systematic development of the science and it is called the Samhita period, when several classical works were produced by numerous authors and during this period there is evidence of organized medical care. Ayurveda is not just the science of healthy living, as it includes prevention of diseases, personal and social hygiene, in addition to the cure of diseases[4]. Being brought up in India, I had the privilege of being raised on preventive natural medicines without knowing the bioactive compounds and their exact mode of action. Most edible plants are also rich in phytochemicals that help to build and maintain a strong immune system. Homeopathy was extensively used by the part of the population in India even in the early 20th century without prescription from certified doctors. Contrary to the conflict of traditional medicine (Ayurveda and Unani) previously not receiving the same treatment as conventional medicine as they do in China[5], now there are many reputed Universities that offer degree programs in these areas. Several steps have been taken in India to promote traditional medicines and to integrate them into clinical practices. Evidence based incorporation of Indian traditional medicine in clinical practices will help to provide a quality healthcare to all[6]. As mentioned in "Medical Botany," enriched with the detailed botanical descriptions and medicinal values of plants, there was little or no interest in Medical Botany in the early 1970s in the United States[5]. Now basic botany courses have been broadly replaced with ethnobotany, economic botany, or medical botany at undergraduate level. Either because of frustrations related to drug resistance, side effects, rising cost of healthcare, or Green Movement, people are willing to integrate conventional and complimentary medicines, consume nutritional food, and participate in more physical activities for healthier lives.

Chronic diseases like diabetes, arthritis, rheumatism, and asthma can be treated using ointments, infusions, and concoctions. In Asia, many endemic, native, and exotic plant species have been consumed or applied for centuries, constituting a repository of knowledge reported in old manuscripts or transmitted by the traditional healers, wild species collectors, and urban gardeners. Data collection procedures in this study utilized the personal narratives of 120 informants from three focus groups[7].

Ethnobotany & Pharmacognosy

Many institutions from developed countries are seeking a partnership for research with native peoples in developing or underdeveloped countries to recognize cultural uses of healing plants in establishing the amount and method of consumption. Raskin *et al.*[8] reported that almost 25% of drugs dispensed in the United States in 1970 were from flowering plants. Many drugs now are analog of those natural phytochemicals. About 250,000 living plant species contain a much greater diversity of bioactive compounds than any chemical library made by humans.

Newman and Cragg[9] have provided a comprehensive review of potential human drugs for cancer, over the time frame from around the 1940s to the end of 2014. According to them, of the 175 small molecules approved, 131, or 75%, are other than "S" (synthetic), with 85, or 49%, being either natural products or directly derived therefrom. Natural products continue to make the most dramatic impact in the area of cancer. They further emphasized that a significant number of natural product drugs/leads are produced by microbes and/or microbial interactions with the "host from whence it was isolated," and therefore it is considered that this area of natural product research should be expanded significantly.

Schmidt *et al.*[10] provide an extensive review of use of alkaloids, terpenoids, glycosides, and other secondary metabolites of plant-origin used in synthesis of conventional drugs and thus considered as analogs. The guidelines for this relatively new regulatory category were released in 2004. Dietary supplements are regulated by the Food and Drug Administration (FDA) under the Dietary Health and Education Act of 1994, but manufacturers are responsible for the safety of the products (https://www.fda.gov/Food/GuidanceRegulation/default.htm).

Botanical drugs are clinically evaluated for safety and efficacy just as conventional drugs, but the process for botanical drugs can be expedited because of the history of safe human use. Botanical drugs are highly but not completely characterized and are produced under the same strictly regulated conditions as conventional pharmaceuticals. Botanical drugs, such as senna and psyllium, can be marketed and sold under the FDA's over-the-counter drug monograph system[11].

Lijun *et al.*[12] conducted in vitro study on effect of terpenes from *Ganoderma lucidum* (GLT) on prostate cancer and reported that GLT administration inhibits the proliferation of human prostate cancer cells and induce apoptosis. The challenge will be the detailed signaling mechanisms and *in vivo* studies which they mention are required to establish GLT as a potential clinical agent for the prevention and/or treatment of prostate cancer.

The bioactive compounds such as antioxidants from plants may be fat soluble or an alkaloid may work in conjunction with other molecules which are consumed culturally. So, there are many challenges of claiming properties of any specific compound in isolation. Mushrooms have gained a lot of recognition in nutrition/medicine, but it's not known how much chitin the human body is able to break to release the bioactive compounds of medicinal value. Research in Pharmacognosy will become much more meaningful when biological concepts will be integrated with social, cultural, ecological aspects of geographical locations.

Integration of Research in the Undergraduate Curriculum

With recent innovations in technology, science education is rapidly transforming to process knowledge efficiently. Proper utilization of technology can help students to conduct investigative, meaningful projects at the undergraduate level within the time constraints of the curriculum[13]. Students well equipped with the conceptualization of biology, botany, zoology, chemistry, ecology, or marine biology in early years of higher education can be directed into guided inquiry-based learning to conduct original research projects. The National Science Foundation strongly encourages and supports research as "An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline or practice" (https://www.nsf.gov). Learning chemistry/biochemistry/phytochemistry in context of applied medical value could motivate students to be engaged in a meaningful way for better academic achievements. Independent Research projects also enhance Information Management along with Critical Thinking Skills and prepare students to be better scientists in the future. These investigations may include simple procedures such as Disc Diffusion Method or Brine Shrimp Mortality Test[14,15]. Isolation, titration, spectrophotometric or DNA studies can also be done and recorded efficiently with the digital instruments available at present time.

Students may be encouraged to share their research in the form of a PowerPoint presentation in a formal colloquium setting with constructive critiquing. Disseminating results of their projects helps students in building communicative skills and ideas for future research in the area. In my "Molecules & Medicines" class, I encourage students to compare a conventional drug with a traditional alternative, or a plant used in their culture for medicinal value, for the same ailment. Exploring the detailed chemical structure of bioactive compounds helps them to recognize the Power of phytochemicals and the science of chemical communication in the human body. Preparing students with scientific skills fulfills many objectives of a science course and helps students to investigate cultural myths to gain evidence-based knowledge. A student in my class from Haiti was keen to test Palm oil as it's widely used in her culture. During initial morphological studies and taxonomical placement, it was recognized that the plant was castor (*Ricinus communis*). She explained that because of palmate leaves, it was considered by locals that this healing plant is a gift from Christ (*Palma Cristi*) and thus it is commonly known as Palm oil. These personal stories during oral presentations make other students recognize the value of natural products and gain respect for other cultures.

Some interesting molecular biology projects can be done to study convergent or divergent evolution of phytochemicals from different geographical locations. It will be extremely informative to trace mutations in different members of the same family or members from different families with similar phytochemicals. Based on availability of resources, the activity can be modified. Instead of hands-on lab for DNA sequencing, FASTA files may be accessed from National Center for Biotechnology Information Company (https://www.ncbi.nlm.nih.gov/).

Medicinal properties of consuming coffee are debatable compared to health-related benefits of chocolate. Inquiry-based projects to explore the taxonomical relationship among main caffeine producing plants can help to understand genomic differences based on environmental stress. Accessed FASTA files of enzymes from caffeine synthesis pathway for *Camellia sinensis* (Theaceae), *Theobroma cacao* (Malvaceae formerly Sterculiaceae), and *Coffea arabica* (Rubiaceae) from NCBI can be used on DNA subway (https://dnasubway.cyverse.org/) to construct a phylogenetic tree. The challenge is that FASTA files for enzymes specifically to trace caffeine synthesis for all these plants are not yet available to be used as a common denominator.

The Future & Scope of Pharmacognosy

With evidence-based investigations in ethnobotany and pharmacognosy, there is an ample opportunity for researchers to explore nature's pharmacy and recognize bioactive molecules, their mode of action, and most importantly side effects. It is of utmost necessity to emphasize the power of phytochemicals which can be extremely dangerous depending upon the concentration. Collection of empirical data combined with the collaboration of researchers and practitioners can help this field to emerge worldwide. It is also an exciting time for ecologists to recognize environmental resistance, struggle for existence, adaptation, and survival of species by utilizing innovative tools of molecular biology, biochemistry, bioinformatics, and many other modern technologies. These studies could resolve numerous taxonomical and ecological issues. After all, plants and animals synthesize these complex secondary metabolites or bioactive compounds for their own survival either to save themselves from predators/pathogens or to attract their mating partners. *'All things are **poisons**, for there is nothing without **poisonous** qualities. It is only the dose which makes a thing **poison**.' – Paracelsus*

Acknowledgments

I would like to thank Prof. Trace Jordan, New York University, for encouraging me to develop "Molecules and Medicines" course and to further my interest in Ethnobotany and Pharmacognosy.

References

[1]Bennett, B.C., 2007. Doctrine of Signatures: An explanation of medicinal plant discovery or dissemination of knowledge? Economic Botany **61(3):** 246-255.

[2]Jackson, M., (Ed.), 2018. *A Global History of Medicine*. Oxford Univ. Press, Oxford, UK.

[3]Lo, V. and M.S. Baker, 2018. Chinese Medicine in M. Jackson (Ed.) *A Global History of Medicine*. Oxford, UK, Pp. 19-43.

[4]Narayanaswamy, V., 1981. Origin and Development of Ayurveda (A Brief History). Ancient Science of Life **I(1):** 1-7.

[5]Lewis, W. H., and P.F. Lewis, 2003. *Medical Botany: Plants Affecting Human Health*. John Wiley & Sons, Inc. Hoboken, New Jersey, USA.

[6]Sen, S. and R. Chakraborty, 2017. Revival, modernization and integration of Indian traditional herbal medicine in clinical practice: Importance, challenges and future. J Tradit Complement Med. **7(2):** 234–244.

[7]Madaleno, I.M., 2015. Traditional Medicinal Knowledge in India and Malaysia. Pharmacognosy Communications **5(2):** 116-129.

[8]Raskin, I., D.M. Ribnicky, S. Komarnytsky, *et al*., 2002. Plants and human health in the twenty-first century. Trends Biotechnol **20(12):** 522-31.

[9]Newman, D.J. and G.M. Cragg, 2016. Natural Products as Sources of New Drugs from 1981 to 2014. J Na. Prod **79(3):** 629-661.

[10]Schmidt**,** B.M., D.M. Ribnicky, P.E. Lipsky and I. Raskin, 2007. Revisiting the ancient concept of botanical therapeutics. Nature Chemical Biology **3(7):** 360-366.

[11]Hassler W.L., 2006. Nonpharmacologic and OTC therapies for chronic constipation. Advanced Studies in Medicine **6(11**)**:** S84-93.

[12]Lijun. Q., L. Sumei, Z. Yumin, C. Jianfan, *et al*., 2017. Anticancer effect of triterpenes from *Ganoderma lucidum* in human prostate cancer cells. Oncology Letters **14(6):** 7467-7472.

[13]Prabhakar, K., 2012. Cultural Myths to Evidence-based Knowledge: Engaging Community College Students in Scientific Exploration. The International Journal of Science in Society **3(2):** 79-89.

[14]Shelley, B.C.L., 2009. Ethnobotany & The Process of Drug Discovery: A Laboratory Exercise. The American Biology Teacher **71(9)**: 541-547.

[15]Chouloute, C. and K. Prabhakar, 2014. Exploring Scientific Evidence about Plant Oils Used in Different Cultures. In Vivo **36(1):** 16-27.

The Metropolitan Association of College and University Biologists thanks the following Affiliate Members for their support

AD Instruments
Anatomy in Clay Systems
BioPac Systems
Cengage Learning
Heyden McNeil Publishing
I. Miller Microscopes
John Wiley & Sons
McGraw Hill Publishing
Micro-Optics Precision Instruments
Pasco Scientific
Pearson Education
W. H. Freeman and Company

Please make every effort to support these affiliate members.
Their participation help us keep registration fees at a reasonable price.

M A C U B

Dr. Edward J. Catapane
Department of Biology
Medgar Evers College
1638 Bedford Ave
Brooklyn, New York 11225