NREL
Transforming ENERGY

BETO 2021 Peer Review
Algae Technology Educational Consortium (ATEC)

March 11, 2021

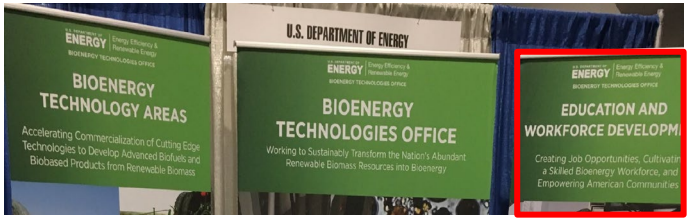
Advanced Algal Systems
Ira “Ike” Levine, Algae Foundation
Cindy Gerk, NREL

Project Overview - what are we trying to do?

BETO's Education and Workforce Development Goals

Improve public accessibility to information about bioenergy production

Design Specialized Education & Training Programs with multiple access strategies



Support formal and informal education, including STEM & vocational programs

Educational Collaborations with national organizations

Engage future scientists and engineers in developing solutions to technical and nontechnical challenges

Establish K-12 STEM opportunities, directed research, internships, and training platforms for future algae farmers, biotechnicians and entrepreneurs

ATEC Progress since 2019 Peer Review

- 12 new partnering universities, community colleges and high school
- 250 Algae Academy Partnering grade schools
- Completed 3 new college courses, MOOC #2, ACES
- 85,000 students/participants
- Created Nationally Endorsed Microcredentialing Digital Badging program

ATEC Goals

- 100,000 students, professionals, entrepreneurs, and aquaculturists taking ATEC curricula offering(s)
- All 50 states served
- 300 collaborating schools, community colleges, and universities
- Microcredentialing Digital Badging System (20 badges)

Market Trends

Product

- Anticipated decrease in gasoline/ethanol demand; diesel demand steady
- Increasing demand for aviation and marine fuel
- Demand for higher-performance products
- Increasing demand for renewable/recyclable materials

Feedstock

- Sustained low oil prices
- Decreasing cost of renewable electricity
- Sustainable waste management
- Expanding availability of green H_2
- Closing the carbon cycle

Capital

- Risk of greenfield investments
- Challenges and costs of biorefinery start-up
- Availability of depreciated and underutilized capital equipment

Social Responsibility

- Carbon intensity reduction
- Access to clean air and water
- Environmental equity

NREL's Bioenergy Program Is Enabling a Sustainable Energy Future by Responding to Key Market Needs

Value Proposition

- Create national algae workforce for new algae bioeconomy jobs
- Enables sustainable farming practices
- Training in algae environmental remediation services

Key Achievements

- ATEC is the first in the nation and BETO's only dedicated algal-based education, training and workforce development program
- ATEC results 96,000 trainees/students, 45 countries
- Corbion, OriGen and PerkinElmer have updated their hiring requirements from a 4-year degree to a 2-year ATEC degree

1. Management

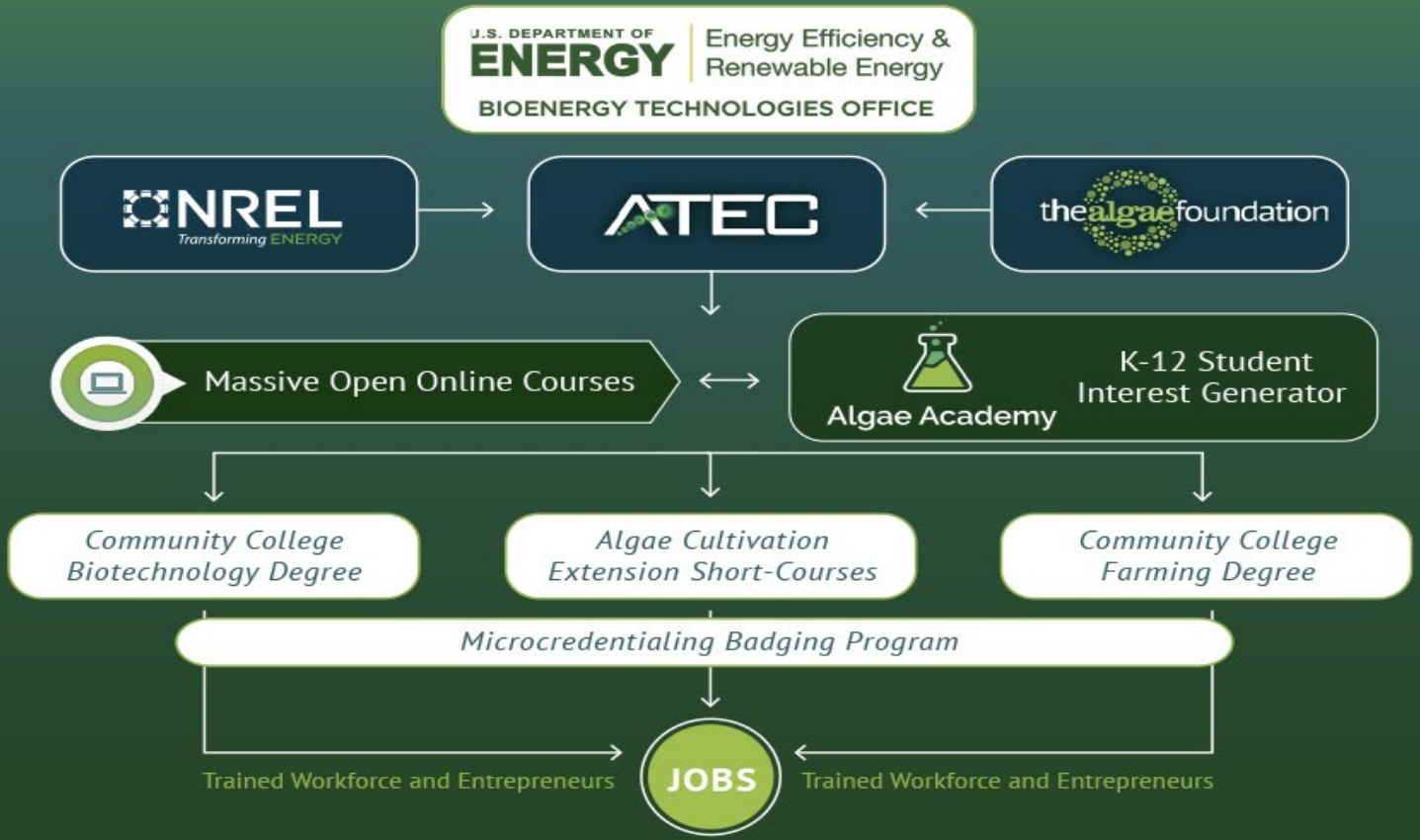
NREL → ATEC ← the algae foundation

ATEC: ALGAE TECHNOLOGY EDUCATIONAL CONSORTIUM

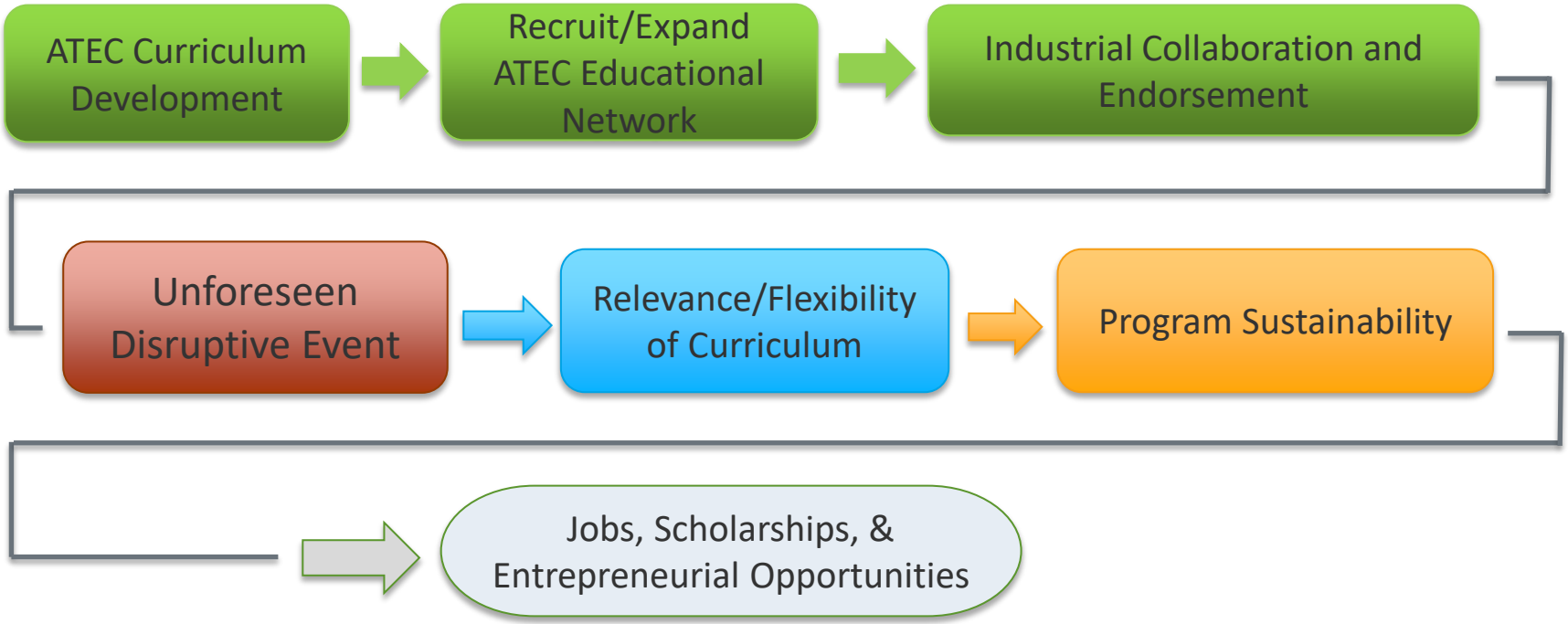
Technical/Project Management: weekly meetings PI & each curriculum committee; monthly meetings with ATEC Team; semi-annual in-person ATEC meetings. Dissemination via publications, presentations, seminars & social media

K-12 STEM	Cultivation curriculum & badging	Biotech curriculum	Field labs/ internships	Online education	Industrial Advisory Board
Algae Academy	SFCC Santa Fe Community College	Austin Community College	AzCATI Arizona Center for Algae Technology and Innovation	Cal-CAB California Center for Algae Biotechnology	ALGENOL
Summer Algae Science Institute – Algal Based Educator Training	NMFR New Mexico Film Resource	UTEX Culture Collection of Algae at The University of Texas at Austin	NREL National Renewable Energy Laboratory	UC San Diego	cellana
University of Southern Maine		Lone Star College	Qualitas Health	the algae foundation	Cyanotech
		Solano Community College	Polaris Renewables		DSM
		Delgado Community College			Earthrise
					GreenWave
					µBio MicroBio Engineering
					Qualitas Health

1. Management



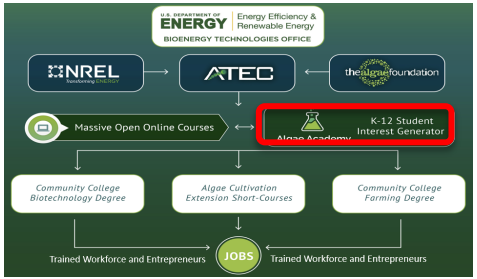
1. Management - Implementation Strategy – what are the risks?



2. Approach - how is it done?

Algae Interest Generators – Algae Academy

EDUCATING STUDENTS ON THE POWER OF ALGAE

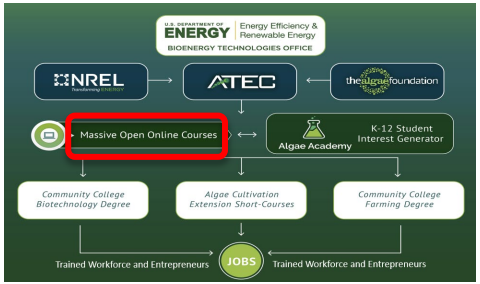


- Assemble curricula team (educators, instructors, academics)
- Align with Next Generation Science Standards
- Promote “Algae as a Career” to grades 11-12
- Recruit teachers (referrals, NSTA presentations, social media)

2. Approach

Algae Interest Generators – Massive Open Online Courses (MOOCs)

- Develop Course Outline (Mayfield and Levine)
- Recruit world class phycologists
- Produce 10-minute presentations with 10 slides
- Publish self-paced and automated lectures
- Offer on Coursera.org (149 partners offering > 2,000 courses)
- Utilize UCSD videography laboratory (post-production editing)



- MOOC # 1 Introduction to Algae

- MOOC # 2 Introduction to Algae Biotechnology

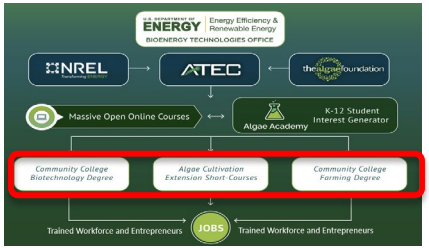
- MOOC # 3 Introduction to Seaweed Biotechnology (in development)

- MOOC # 4 Algae New Products and Polymers (planning stage)

2. Approach

ATEC Algae Cultivation & Biotechnology Curricula (academic & extension platforms)

- Provide cost-effective job training & workforce development
- Create a pathway to higher education
- Teach entrepreneurial skills
- Generate learning outcomes and skillsets determined by IAB consultation and pedagogy professionals
- Improve with external curriculum assessment committee
- Recruit schools with existing infrastructure
- Furnish training and support for instructors



ATEC Prepares People to Get Bioeconomy Jobs

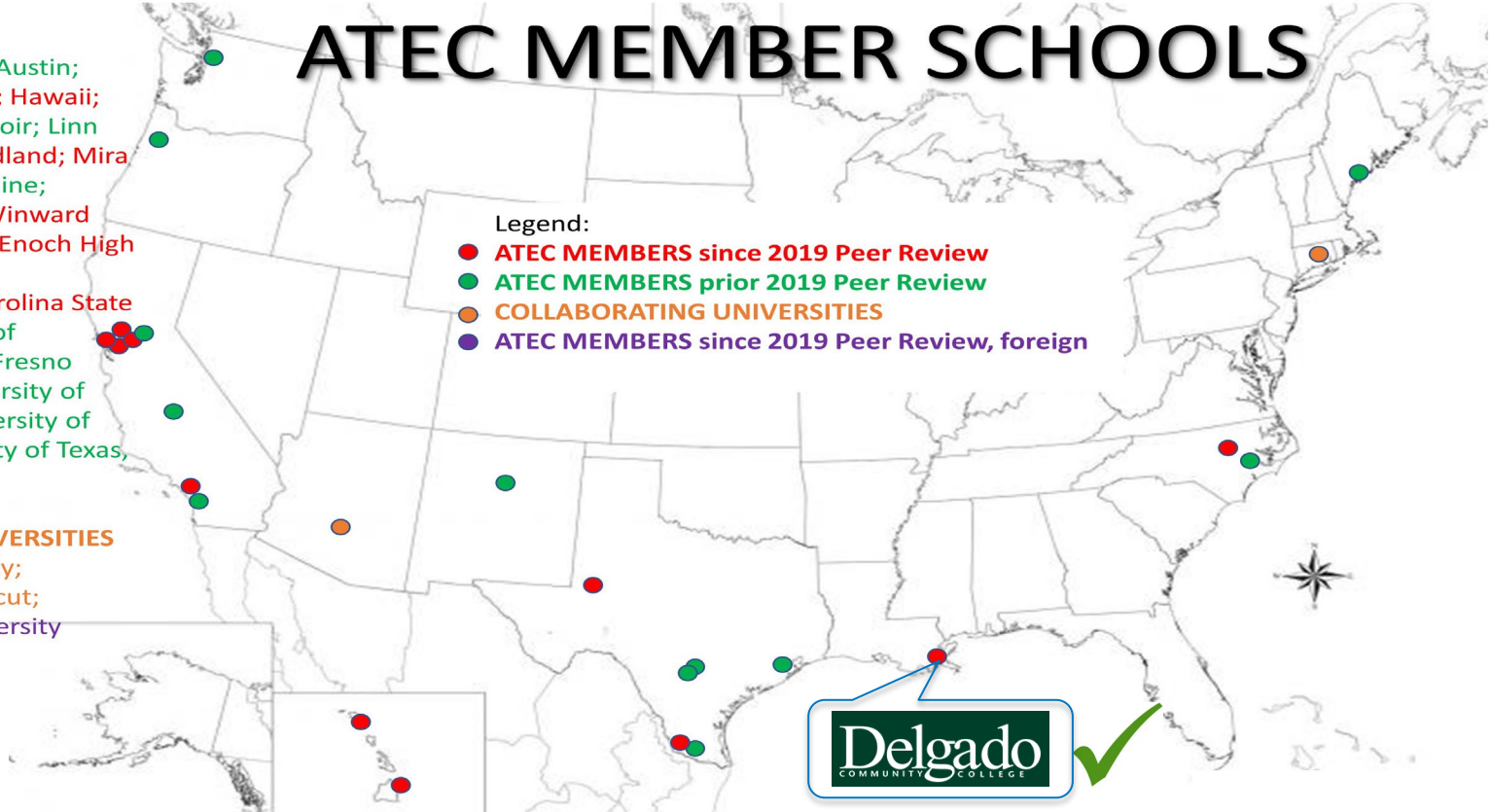
3. Impact - why is it important?

Go/No-Go Completed March 2021

Initiate ATEC Curriculum at **one** new partnering institution. (**12 new partnerships**)

ATEC MEMBERS
Community Colleges: Austin; Contra Costa; Delgado; Hawaii; Laney; Las Positas; Lenoir; Linn Benton; Lone Star; Midland; Mira Costa; Santa Fe; Shoreline; Solano; South Texas; Winward
High School: James C. Enoch High School
Universities: North Carolina State University; University of California, San Diego; Fresno State University; University of Southern Maine; University of Texas, Austin; University of Texas, Rio Grande Valley

COLLABORATING UNIVERSITIES
Arizona State University;
University of Connecticut;
Incheon National University

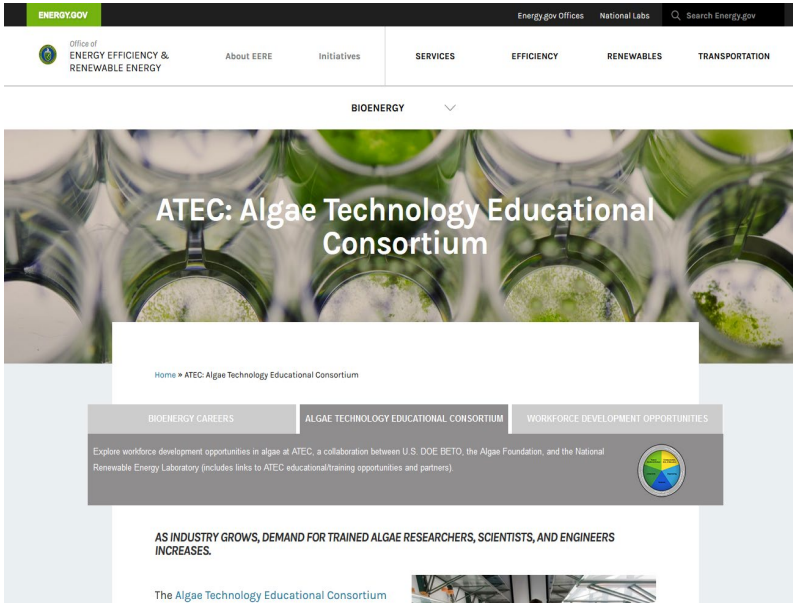


3. Impact

Premier Program for BETO's Education and Workforce Development

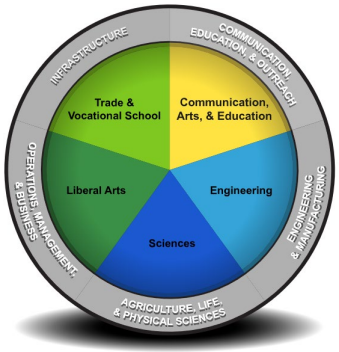
- Promote ATEC program on BETO's website and Career Exploration Wheel
- Disseminate ATEC progress
  - 2 publications and 15 presentations
  - Social Media (4,699 friends, followers, members)

Twitter LinkedIn Instagram Facebook



https://www.energy.gov/eere/bioenergy/atec-algae-technology-educational-consortium

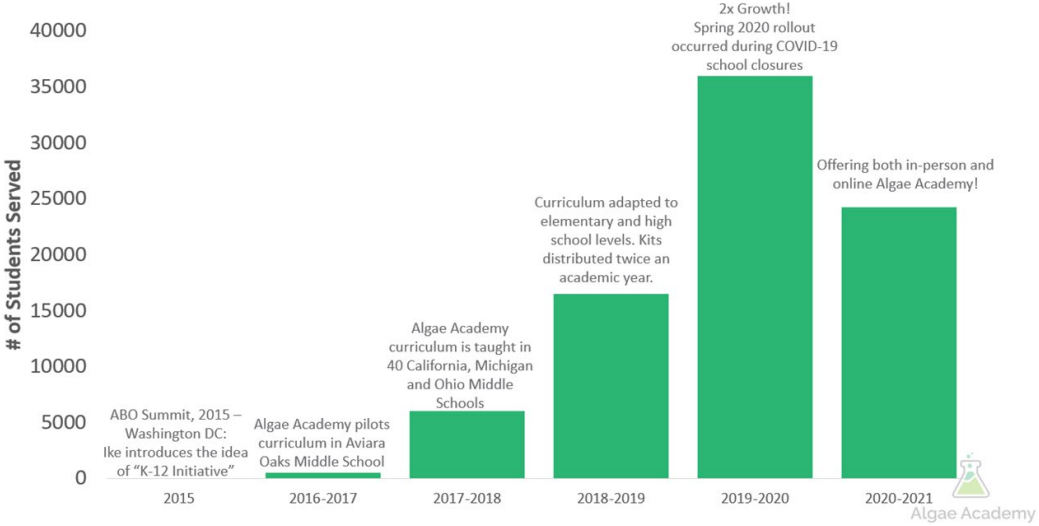
Career Exploration Wheel



3. Impact

Algae Academy

EDUCATING STUDENTS ON THE POWER OF ALGAE

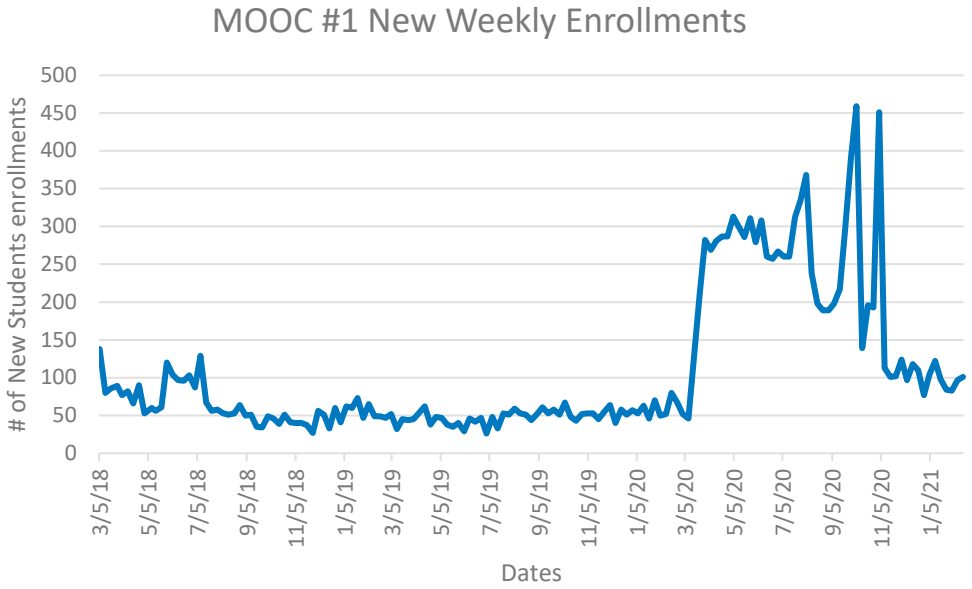


COVID-19 Response: 50% Academic Year 2020-2021 accessed training online.

3. Impact

Algae Massive Open Online Courses (Algae MOOCs)

- **Introduction to Algae MOOC #1**
- 16,831 students (98% approval rating)
- 10% received a pay increase or promotion
- 43% received a tangible career benefit from this course
- **Algae Biotechnology MOOC #2**
- 875 students



3. Impact

Community College Algae Cultivation Certificate Degree Program

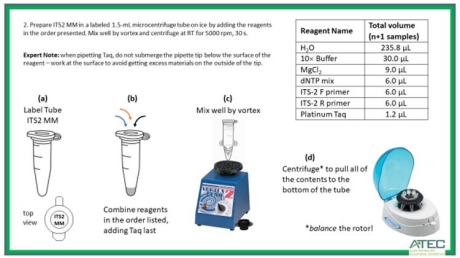
- 250 participating students (cumulative - 4 years)
- Recruitment of graduates by algal farms
- Conversion from in-person courses to online format (5 classes)
- Development of heterotrophic cultivation curriculum (Fall 2021)
- Initiate seaweed cultivation community college courses (academic year 2021-2022)

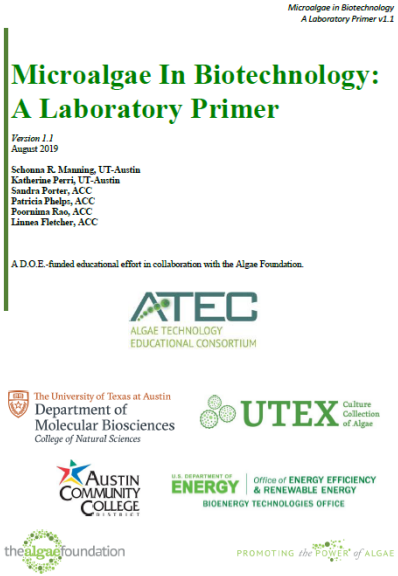
* ATEC cultivation curriculum located in supplemental slides

3. Impact

New Concepts in Algae Biotechnology Pedagogy

- 1500 participating students (cumulative – 3 years)
- Completion of Biotech Lab Primer (Nov 2019)
- Completion of Intensive I and Intensive II lab courses (Sep 2020)
- Completion of **I**mage **G**uided **S**tandard **O**perating **P**rocedures (Jan 2021)





Kalyani Maitra, Ph.D.
Assistant Professor, Department of Chemistry and Biology
California State University, Fresno

"The IGSOPs have been done with great care and detail to not only enhance student understanding but also aid a students'/instructors' preparation of the lab. The experiments in the Primer are very well written and are reproducible to give students a good perception of Algal Chemistry. My students in the research lab have also started employing some of these techniques and have been producing results as good as the techniques that we employed earlier from other journal articles."

* ATEC biotechnology curriculum in supplemental slides

3. Impact

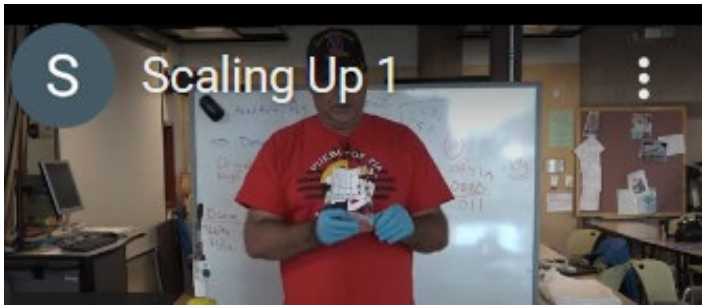
Online Learning Opportunities

- Aquaculture Extension Short-Courses (ACES)

  Registrations from 45 countries

  - Part 1. Seaweeds
    - Published Mar 2019
    - 1,068 Registrations

  - Part 2. Microalgae
    - Published Aug 2019
    - 645 Registrations



4. Progress and Outcomes

Curriculum Development for Completion of AOP Milestones (FY20)

✓	Initial social media campaign to increase awareness and heighten support for algae	FY20 – Q1
✓	Complete Intro to Phycology course	FY20 – Q2
✓	Significantly increase ATEC curriculum participation / formalize MOU with one additional college	FY20 – Q3
✓	Complete Algaculture 2 (online) (1 class)	FY20 – Q4

Additional deliverables were generated in the course of completing the AOP FY 20 milestones

- Completed and published Algae Biotechnology MOOC #2
- Provided **FREE** downloadable textbook for ATEC students
- Completed Biotechnology Labs featuring Image Guided Standard Operating Procedures (**IGSOP**)
- Expanded Algae Academy, offered grades 2-5 and advanced placement
- Mitigated Risks – programmatic efforts downgraded all risk factors
- **Reached 96% of final goal of 100,000 participants with 24 months remaining**

4. Progress and Outcomes

Curriculum Development for AOP Milestones (FY21)

✓	Algae Biotechnology Training Modules	FY21 – Q1
	Heterotrophic Lectures/Labs	FY21 – Q2
	Micro credentialing digital badge program	FY21 – Q3
	MOOC #3: Introduction to Seaweed Biotechnology	FY21 – Q4
	New online courses in the Algae Cultivation program at SFCC	FY21 – Q4

Future Efforts:

- Expanded curricula: fermentation and heterotrophic systems, genetic engineering, wastewater treatment, new product development, & offshore seaweed farming
- Institute quantitative and qualitative evaluations
- Enhance student retention and graduation rates

4. Progress and Outcomes

External Certification and Endorsement Programs

- ATEC microcredentialing digital badging program endorsed by ABO
  - Presents valuable employment verification tool
  - Verifies candidate skills
  - Awarded first badges Dec 2019
  - 2020 certification suspended due to COVID-19 (20 badges scheduled)

- Intro to Microscopy
- Basic Measurements and Safety
- Culture Isolation and Maintenance
- Culture Scale-up
- Productivity Measurements
- Data Collection & Recordkeeping

ABO
ALGAE BIOMASS ORGANIZATION

National Third Party Endorsement July 22, 2019

4. Progress and Outcomes

Expand collaborative relationships with national organizations

- InnovATE*BIO*: National center grant based at Austin Community College offers access to the nation's community college biotechnology programs
- National Science Teacher Association (NSTA) provides access to 40,000 science teachers and larger source of Algae Academy enrollees
- Future Farmers of America provides direct access to 8500 chapters and 750,000 students
- USDA – NIFA awarded grant in 2020 supporting Algae Academy adding to BETO funds sustainability

Quad Chart Overview (for AOP Projects)

Timeline
- Project start date: 10/01/2015
- Project end date: 9/30/2022

	FY20-FY22	Active Project
DOE Funding	(10/01/2020 – 9/30/2022)	FY20 $480K FY21 $600K FY22 $600K

Project Partners
- Algae Foundation

Barriers addressed
- Aft-A Biomass Availability and Cost
  - Geographically expand algae cultivation and reduce employee training costs. ATEC MOOCs provide professional development training
- Aft-B Sustainable Algae Production
  - Interdisciplinary expertise and skilled workforce training platforms increase production efficiencies
- At-G Social Acceptance and Stakeholder Involvement
  - Industrial Advisory Board enhances private-public-partnerships

Project Goal
Develop and implement new collaborative educational programs ranging from K-12 to community college degrees and extension short courses.

End of Project Milestone
Provide a flexible, sustainable, educational curriculum and training programs reaching 100,000 participants producing the next generation of algal cultivation, biotechnology and bioeconomy professionals, reduce workforce training costs and increasing algal production while generating momentum in advancing algal technologies in industry

Funding Mechanism
AOP Annual funding

ATEC Prepares People to Get Bioeconomy Jobs

Management

- 250+ schools/ 40+ staff, consultants, and volunteers/ 6 major divisions
- Horizontal management philosophy
- Structured scheduled meetings/collaborations
- Identify and mitigate risks/challenges
- Curriculum relevance maintained through IAB

Approach

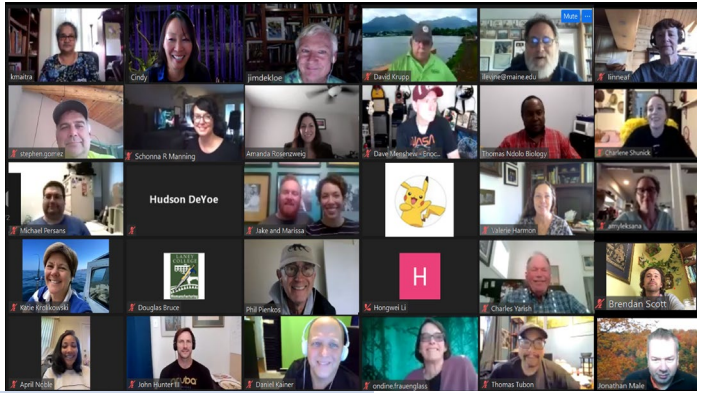
- State-of-the-art curriculum development and innovative future algae topics
- COVID-19 pivot to online education
- Dissemination through BETO workforce development web platform and social media

Impact

- **>96,000 total ATEC participants to date**
  - 150 Farming college students
  - 1,500 Biotechnology college students
  - >17,000 Algal MOOC participants (> 10 countries)
  - 1,700 ACES trainees (45 countries)
  - 76,000 Algae Academy
- COVID-19 Pivot

Progress and Outcomes

- Programmatic and curriculum development
- Microcredentialing badging program
- National Organization Collaborations establishing access to:
  - NSTA – 40,000 Science Teachers
  - FFA – 750,000 Farming Students
  - InnovATE*BIO* – > 100 biotechnology degree granting colleges



ATEC virtual meeting Oct 2020

ATEC in-person meeting Mar 2020

Thank you!

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Additional Slides

Abbreviations and Acronyms

ABO – Algae Biomass Organization
ACC – Austin Community College
ACES – Algae Cultivation Extension Short-courses
ATEC – Algae Technology Educational Consortium
AY – Academic Year
BETO – Bioenergy Technologies Office
DOE – Department of Energy
FY – Fiscal Year
IAB – Industrial Advisory Board
MOOC – Massive Online Open Course
NGSS - Next Generation Science Standards
NREL – National Renewable Energy Laboratory
SFCC – Santa Fe Community College
STEM – Science, Technology, Engineering, and Mathematics
UCSD – University of California, San Diego
UTEX – University of Texas, Austin

Response to Reviewers' Comments 2019

Weakness: Establishment of new programs at the college level is very expensive and potentially limited especially in states with high potential for algal bioeconomy.

New programs can be very expensive for any adopting community colleges. The awareness that schools have limited funds for program expansion and understanding the potential costs of both the algal cultivation and algal biotechnology degree programs, ATEC identified and collaborated with "Tier One Schools". The ATEC definition of Tier One Schools is an institution with existing infrastructure and equipment to support either of the ATEC degree programs. Examples include: 1. Santa Fe Community College (SFCC) with existing infrastructure supporting algal biofuels, green house management, wastewater treatment, and aquaponics programs did not require any capital investment to adopt the ATEC curriculum; 2. Austin Community College (ACC), Lone Star College and Solano Community College have all built massive biotechnology programs long before their ATEC collaboration began. ACC alone has 600 biotechnology majors on three massively equipped campuses. Zero capital investment was required for any of these schools to adopt the ATEC curriculum; 3. Midland College of Midland, TX sits in the heart of the Texas oil boom and is tremendously supported by local industry. ATEC is currently in negotiations with Midland College to join and there are discussions to adopt both degree programs and the Algae Academy's K-12 effort as there is a specialized high school on the college campus. The school has indicated capital costs are not a restriction to adoption of the ATEC curriculum; and 4. The most common scenario is "Second Tier Schools", those schools lacking in the infrastructure for either degree program and no desire to build the needed infrastructure to adopt either of the ATEC curricula. ATEC anticipated students from schools not equipped to offer our curriculum wanting to participate and as a result built an online component to our college curricula. In addition to the online courses, ATEC developed intensive, one week, face-to-face lab classes, regionally offered to our online students providing them with the critical hands on skills to complete their efforts. Our blended strategy provides access to the vast majority of community colleges where individual students may want to enter the algal commercial career path while there is little interest by their individual schools to invest in new degrees or program infrastructure.

Response to Reviewers' Comments 2019

Weakness: It is difficult to know what portion of the success to date is due to the fact that the program is free and whether there is enough demand to move the college curriculum to stand alone.

All efforts of the Algae Foundation and ATEC are free including: Algae Academy's K-12 Algal STEM kits reaching ~ 20,000 students in 36 states during the 2018-2019 academic year; Introduction to Algae Massive Open Online Course (Algal MOOC) reaching ~ 4000 students and currently growing by 60-90 new students each week; ~ 400 community college students enrolled in algal courses; and Algae Cultivation Extension Short-courses (ACES) were publicly released April 15, 2019 so utilization data will be forthcoming. The community college curriculum is NOT free to the students. All community college students pay tuition to their respective institutions for each of their credited college courses. ATEC receives zero tuition dollars from their adopting community college partners and collaborators. Student feedback has been excellent, and we expect continued strong response to ATEC's curriculum as students gain more interest and excitement in this growing field.

We recognize the concern for "enough demand". ATEC has developed an understanding that the typical rural community college student resists relocating away from home and family in search of a job and/or career. Fifty percent of our graduates have taken an entrepreneurial route and started their own algae companies minimizing the potential for local company candidate oversupply.

Response to Reviewers' Comments 2019

Weakness: There may be an opportunity for alternative feedback mechanisms such as the perspective of the employer of the students. Now that the program has been established, the goals should be reassessed to continue to drive the program forward.

ATEC completely agrees with the sentiment in this stated weakness, but we see this as a significant part of the curriculum operational plan. Formal and informal feedback, internal and external assessment, student evaluations, and employer dialog are built into the ATEC model. The ATEC Industrial Advisory Board represents an estimated 90% of the algal biomass produced in the United States and their feedback concerning skills and learning outcomes is essential to building and updating ATEC's curriculum. The Algae Foundation's Board of Directors lends ATEC access to the current and future strategies and technologies for moving the industry forward. Flexibility, editing and updating the curriculum is an essential effort of ATEC currently and into the future. Proof of this prioritization includes: 1. Commissioning an external curriculum advisory committee to review the Santa Fe Community College (SFCC) curriculum just two weeks after its first graduating class in May 2018; 2. The biotechnology curriculum reviewed last Friday, April 12, 2019 by the Austin Community College (ACC) biotechnology advisory board made up of executives of the Texas biotech community. The ATEC algal biotechnology curriculum's inclusion in the ACC biotechnology major was unanimously endorsed by this board; 3. Informal feedback from the first SFCC graduating class' engagements include rave reviews from NREL (internships) and local algae companies (employees); and 4. ATEC received feedback that there needed to be a greater coverage of electrical wiring and remote sensing. Each of these efforts are being enhanced in our Pumps and Motors course.

Project Overview

ATEC provides a cost-effective algal-based educational curricula to develop a skilled workforce in support of BETO's education and workforce development goals. ATEC has provided in-class, hybrid, on-line and extension learning and training opportunities to 75,000+ students, corporations, aquaculturists, biotechnologists, and farmers

ATEC has conquered the challenges from COVID-19 related restrictions by pivoting to online curricula

ATEC actively collaborates with businesses, national labs, academics, and instructors providing education and training opportunities in support of the algal-based bioeconomy

ATEC overcomes the risk of becoming irrelevant by expanding into additional areas of commercial importance that include heterotrophic cultivation and seaweed commercialization

2. Approach

Critical Success Factors	Risk	Strategy/Abatement
ATEC curriculum development	Design industrial based algal curricula for training and education	Recruit educators and IAB members to design programs. Expand curricula to include macroalgae, heterotrophic cultivation and genetic engineering (# classes completed/offered)
Recruit/expand ATEC educational network (Go/No-Go March 2021)	Establishment of new degree / certificate programs, national learning standards accreditation	Collaboration with InnovATEBIO, NSTA and FFA. Document success of trainee opportunities at national labs, companies, & universities (# new schools/yr)
Industrial collaboration and endorsement	Acceptance of learning outcomes and job skills	Collaboration with ATEC Industrial Advisory Board; industry endorsement of micro credentialing program (# new IAB members)
Unforeseen disruptive events (COVID-19)	No in-person learning in labs. Restrictions and facility closures	ATEC created IGSOP labs, online courses, national webinars and moved SASI to online (# online classes)
Relevance/flexibility of curriculum	ATEC curriculum to stay up-to-date with required skills as technology evolves	Enhance collaboration with IAB to ensure that ATEC curriculum provides necessary training and education required by emerging algal technologies (bi-annual external curriculum assessment)

2. Approach

Critical Success Factors	Risk	Strategy/Abatement
Sustainability of programs	ATEC program self-sufficiency upon conclusion of BETO funding	ATEC curriculum, labs, textbook, MOOCs, ACES remain accessible to the entire ATEC network beyond BETO funding. Single program requiring additional funds include the Algae Academy, which the Algae Foundation is committed to funding long-term (USDA, NGO, private foundations) (# grant submissions/year)
Jobs, scholarships, entrepreneurial opportunities	Student awareness of algae technology and job demand in the algal industry.	ATEC's internship clearinghouse provides both paid/non-paid internships. Social media and newsletter disseminates employment opportunities (# social media followers/quarter)
	Potential job market saturation	ATEC program participants occupy multiple levels of the bioeconomy including farmers, technicians, lab professionals, etc. ATEC graduates represent enhanced candidates appropriate for algal-based and alternative bioeconomy positions eliminating potential for saturation (# badges, enrollees, graduates)

3. Impact

Michael Persans, Ph.D.

Professor, Department of Biology

University of Texas, Rio Grande Valley

"I am currently working to incorporate the ATEC Biotechnology Labs and IGSOPs into my teaching classes and research lab. These sessions were very useful to understand the techniques."

3. Impact

"As stated in *The Federal Activities Report on the Bioeconomy: Algae,* the interagency collaborative vision is a "vibrant U.S. bioeconomy that enhances economic growth, energy security, and environmental quality by maximizing the sustainable use of the nation's domestic biomass resources for affordable biofuels, bioproducts, and biopower". The basis for realizing this opportunity will depend on a well-educated, technically competent and inspired workforce. ATEC is a proven initiative that is providing education and job ready skills for a diverse population and a keystone for the future of the US bioeconomy."

Jill Kauffman Johnson

Board Chair, Algae Biomass Organization and Executive Advisor, Sustainability and Society, Corbion

3. Impact

“Algae are a key climate change solution for our future. The algae industry supports many sustainable and renewable technologies touching everything from products in food, feed, fuel, fertilizers, and materials to services such as carbon capture, wastewater treatment, and ecosystem services. **The ATEC training and workforce development program is critical to the success of the industry** - developing students into the operators, scientists, engineers, and entrepreneurs that will drive and expand the industry as it continues to grow.”

Rebecca White
Executive Director
Algae Biomass Organization

3. Impact

Relevance of ATEC to BETO Mission:

- Qualitas VP indicated desire to hire the entire SFCC 2019 ATEC graduating class **[Barrier Aft-A Biomass Availability and Cost]**
- ATEC's Intro to Algae Massive Open Online Course participation by existing staff was mandated by Cyanotech **[Barrier Aft-A Biomass Availability and Cost]**
- ATEC curricula and network of community colleges, universities, and extension programs provide the opportunities to generate a skilled workforce to fill emerging U.S. algal bioeconomy positions including related fields (wastewater treatment, fermentation, biotechnology, multitrophic aquaculture, greenhouse horticulture, plant nurseries) **[Barrier Aft-B Sustainable Algae Production]**
- ATEC will provide training and interdisciplinary expertise for crossover applications in wastewater, fermentation, and biotechnology industries and embraces private-public-partnerships to provide a skilled workforce **[Barrier At-G Social Acceptance and Stakeholder Involvement]**

4. Progress and Outcomes

Internship clearing house

Create near-term job potential: Upon completion of the ATEC curriculum, graduates created new companies, providing opportunities for additional future graduates

Providing student opportunities at national labs, companies, & universities

- NREL – Zachary DeLay from SFCC
- Qualitas – Melba Diaz from Lone Star

FY20 Milestones

Milestone Name/Description	Criteria	End Date
Initiate social media campaign: increase awareness to the general public to heighten support and publicity of ATEC highlights. Impact shall be the additional growth and interest in ATEC curriculum in community colleges and ATEC online course participation	50 ATEC Social Media Program Posts (Oct-Dec)	12/31/2019
Complete Intro Phycology Course: This in-person course will be embedded in the Cultivation Curriculum at SFCC and Hawaii Community College	This in-person course shall be ready for Fall 2020 semester	3/31/2020

FY20 Milestones

Milestone Name/Description	Criteria	End Date
<u>ATEC Curriculum participation:</u> ACES student census	250 total ACES registrations	6/30/2020
Community College / University Student Participation in ATEC Curriculum	500 community college / university student participants	
Algae Academy K-12, STEM Initiative to promote growth and interest in algae: 1. Teacher Training; 2. K-12 STEM kits in classrooms	1. Three Algae Summer Science Institutes offered at partnering community colleges 2. 15,000 participating students, and 35 participating states	
MOOC (Massive Open Online Course)	Achieve 2,500 MOOC student participation	

FY20 Milestones

Milestone Name/Description	Criteria	End Date
Algaculture 2: Develop advanced cultivation, 10L to commercial	Add one online course to ATEC Algal Cultivation curriculum at SFCC	9/30/2020
Formalize additional new college ATEC Partnerships (MOU)	Add 3 new MOUs to accept ATEC curriculum at community colleges / universities	

FY21 Milestones

Milestone Name/Description	Criteria	End Date
Algae Biotechnology Training Modules: Seven primer Image Guided Standard Operating Procedures training modules will be produced and ready for ATEC curriculum use. (UTEX)	Seven primer training modules are released and available for use on January 1, 2021	Dec 31, 2020
Heterotrophic Lectures: Establish and implement a classroom module (lecture presentation) to teach fundamentals of heterotrophic algae cultivation. (Polaris Renewables)	Offered at Solano Community College for fall semester 2021. Course deliverables will include learning outcomes, teaching notes, lectures, and presentations. Stretch Milestone: Implement classroom module at Laney Community College and Contra Costa Community College.	Mar 31, 2021
Micro credentialing digital badge program: Define/list new badges for Algaculture 1 at SFCC.	SFCC shall acquire and provide accreditation for 12 current + new badges and award 20 badges of successful completion. Train and certify instructors for ATEC badges. Stretch Milestone: Define/list Algaculture 2 and Algaculture 3 from SFCC. Define/list 11 badges from Lone Star	Jun 30, 2021

FY21 Milestones

Milestone Name/Description	Criteria	End Date
MOOC #3: Introduction to Seaweed Biotechnology: Develop, produce and publish for immediate participation a third FREE self-paced Massive Open Online Course (MOOC) entitled, “Introduction to Seaweed Biotechnology”.	MOOC #3 will be available for online participation through the University of California, San Diego and/or Coursera.	Sep 30, 2021
New online courses in the Algae Cultivation program at SFCC: Develop, produce and publish for immediate participation the following three courses ALTF161 (Intro to Algae Cultivation) and ALTF261 (Advanced Algae Cultivation), ALTF262 (Algae Harvesting) as 3-credit online courses.	ALTF161 (Intro to Algae Cultivation) and ALTF261 (Advanced Algae Cultivation), ALTF262 (Algae Harvesting) will be available for online participation through the Santa Fe Community College.	Sep 30, 2021

Publications

- Ganesan, M., N. Trivedi, V Gupta, S Venu Madhav, CRK Reddy, and I A Levine. 2019. Seaweed resources in India – current status of diversity and cultivation: prospects and challenges. Botanica Marina 62(5): https://doi.org/10.1515/bot-2018-0056

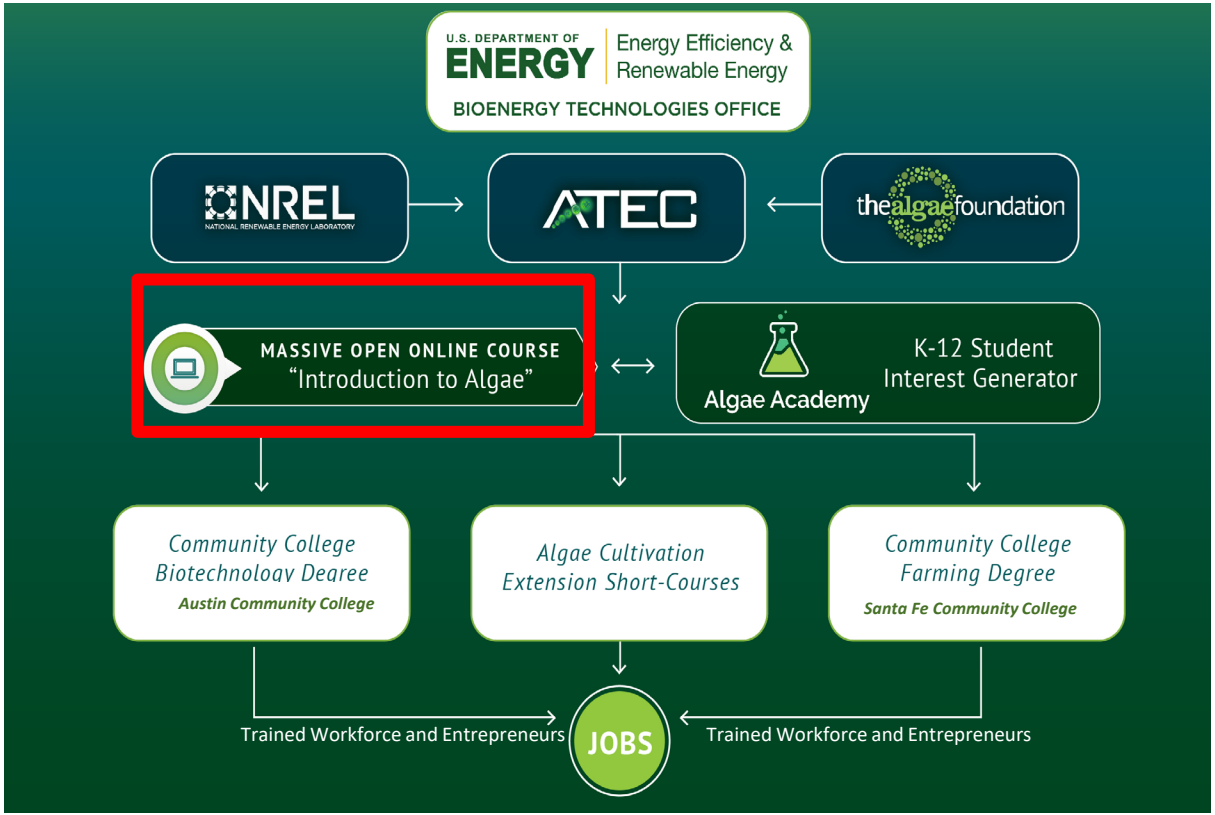
- Levine, I. and C. Gerk. 2021. The Algae Foundation and Algae Technology Educational Consortium. J. of the World Aquaculture Society. JWAS 20-232. Submitted.

Presentations

- Levine, I. 2020. Workforce development and educational initiatives. Algae Biomass Summit. Plenary Lecture. September 10, 2020. Virtual.
- Levine, I.A., G. Flimlin. 2020. Algae Foundation's Algae Cultivation Extension Short-courses. Aquaculture America 2020. February 12, 2020. Honolulu, HI
- Levine, I.A. 2020. Micro and Macroalgae Education and Training Opportunities. Maine Aquaculture Research, Development and Education Summit, January 17, 2020. Belfast, ME.
- Levine, I., T. Cannis, J. Nalley. 2019. Algal-based bioeconomy workforce training and education: Algae Foundation's Algae Technology Educational Consortium (ATEC) 2019 and beyond. European Algae Biomass Association's AlgaEurope. December 3, 2019. Paris, France.
- Levine, I., T. Cannis, M. Carr, G. Mitchell, J. Nalley, and R. White, 2018. Algal-based Education K-14 and Beyond. Algae Biomass Summit. Plenary Lecture.
- Levine, I., L. Fletcher, S. Gomez, and J. Nalley. 2019. Interested in Learning About Emerging Algae Technologies? ATEC Can Help. HITEC. July 24, 2019. St. Louis, MO.
- Levine, I. 2019. Algae Foundation's Algae Technology Educational Consortium (ATEC) and the Algae Academy: 2019 and beyond. 9th International Conference on Algae Biomass, Biofuels, and Bioproducts. Plenary Lecture. June 18, 2019. Seattle, WA.
- Levine, I. 2019. Learning science from K-Gray. NSTA19: National Conference on Science Education. St. Louis, MO. April 11-14, 2019.
- Levine, I. 2019. Algal-based bioeconomy workforce training and grades K-12 STEM education: Algal cultivation and biotechnology in USA. Blue Agriculture: Biotechnological advances in exploring the ocean for food and nutraceuticals. Barranquitas, Puerto Rico. April 8-9, 2019
- Levine, I. 2019. The algae industry and why algae curricula in college education is important for the future. Science Seminar Midland College. Midland, TX. April 5, 2019. Invited.

Presentations

- Levine, I. 2019. Algae Foundation's Algal-based STEM K-16 Education Initiatives. USM Research & Scholarship Symposium. Portland, ME. March 29, 2019
- Levine, I. 2019. Algal-based bioeconomy workforce training and K-12 STEM education: Algal farming renaissance in Maine an Iceland. Strandbunadur 2019. March 21-22, 2019. Reykjavik, Iceland. Invited
- Levine, I. and C. Gerk. 2019. Algae Technology Educational Consortium. U.S. D.O.E., BETO 2019 Project Peer Review. March 4-7, 2019. Denver, CO. Invited
- Levine, I. 2019. Algal-Based Educational Initiatives Supplying the Next Generation of Specialists for Algal Industrialization. Algal Bioeconomy, Maine Seaweed Renaissance a Prime Example for Indian Seaweed Commercialization. India International Seaweed Expo and Summit. January 22-24, 2019. Mumbai, India. Invited.
- Levine, I. 2019. Algal-Based Bioeconomy: Education, Training & Commercial Opportunities. Reliance Industries Limited. January 21, 2019. Mumbai, India. Invited.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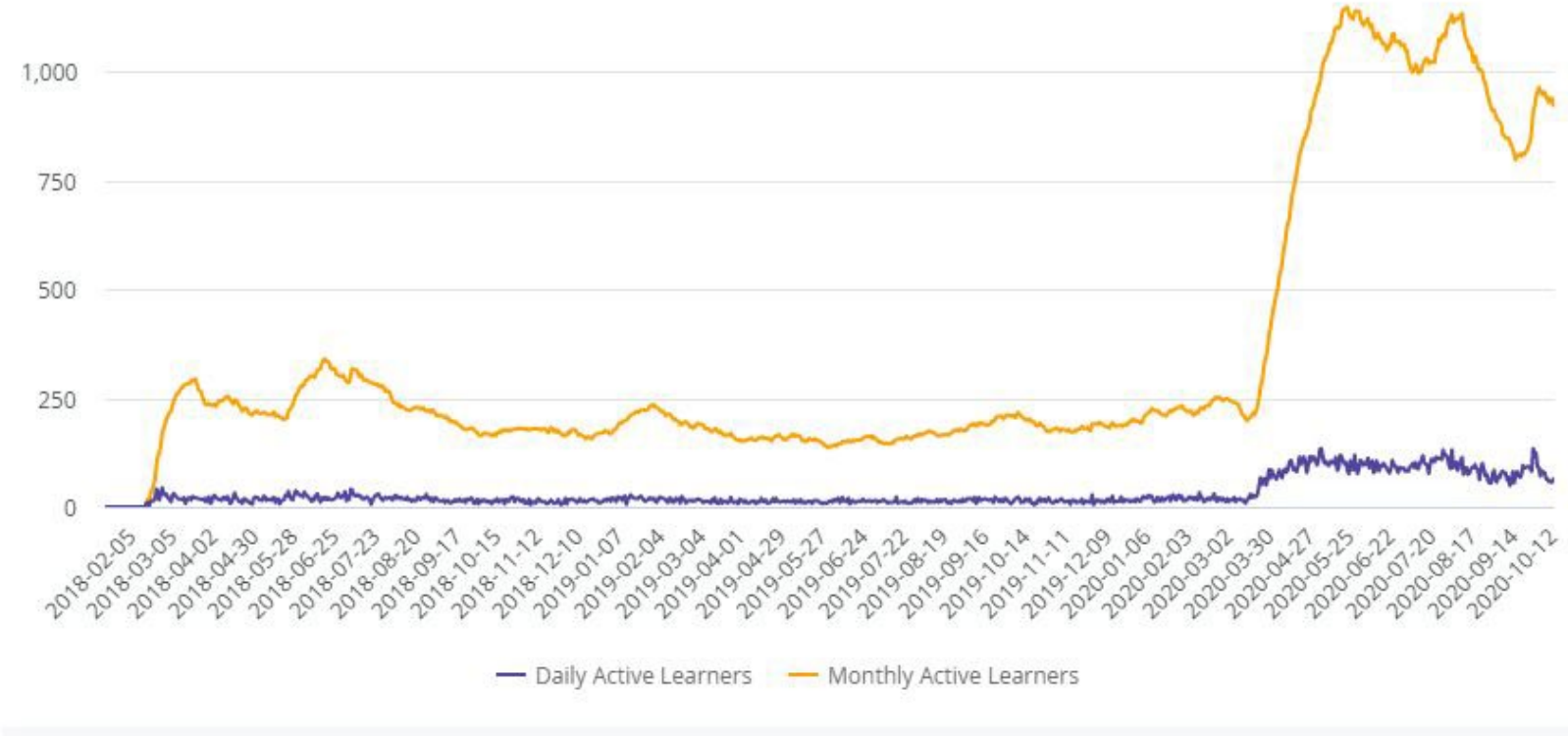
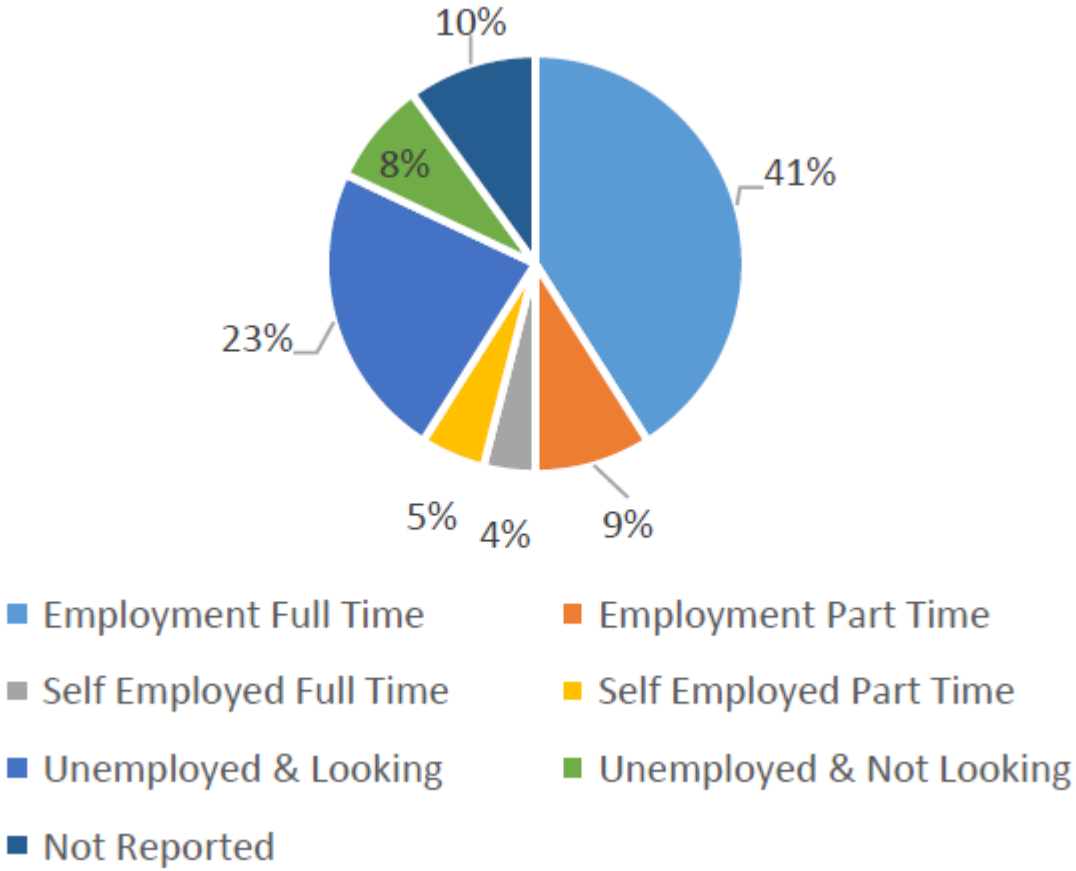
Trained Workforce and Entrepreneurs
JOBS
Trained Workforce and Entrepreneurs

Algal MOOC #1 Daily and Monthly Active Learners as a Function of Time.

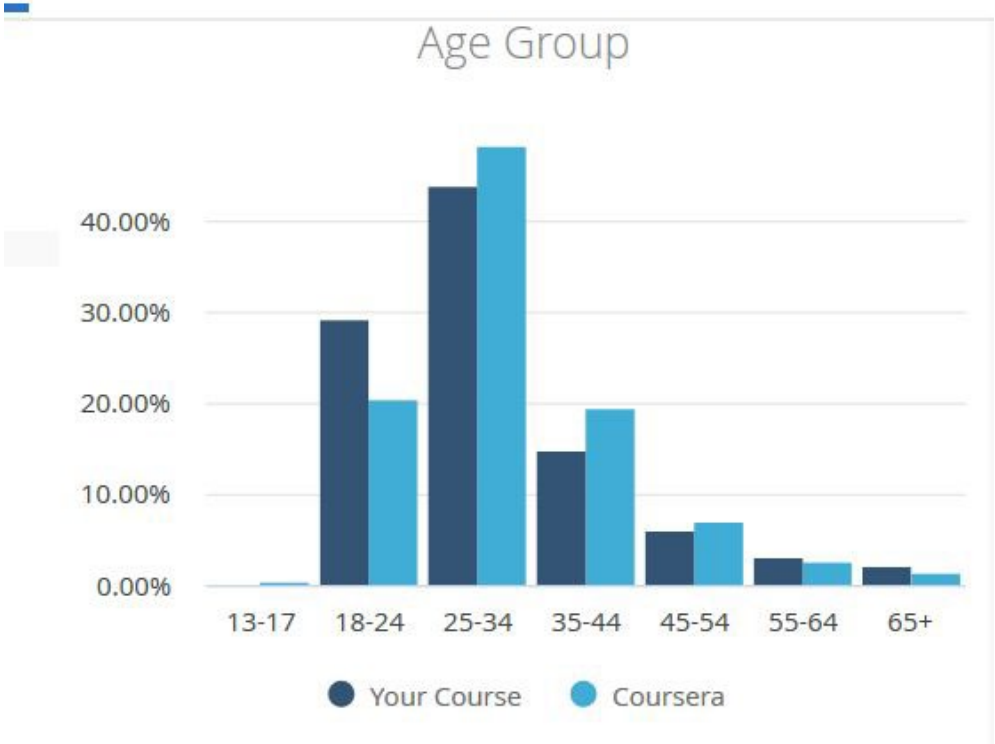


Algal MOOC #1 Employment Status

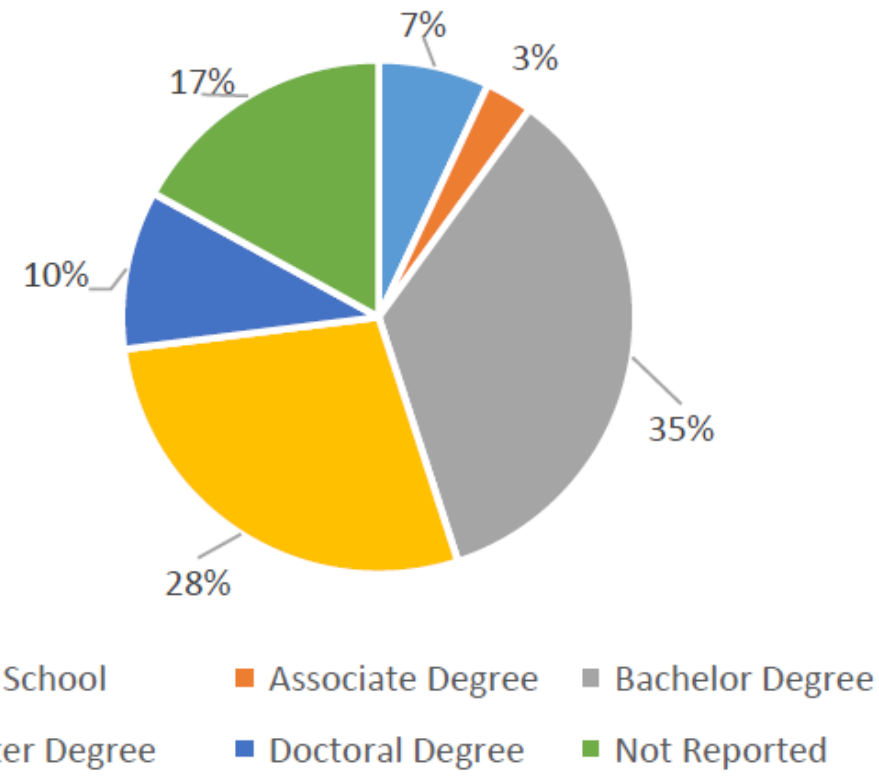


Algal MOOC #1 Student Employment Status as Compared to All Coursera Courses

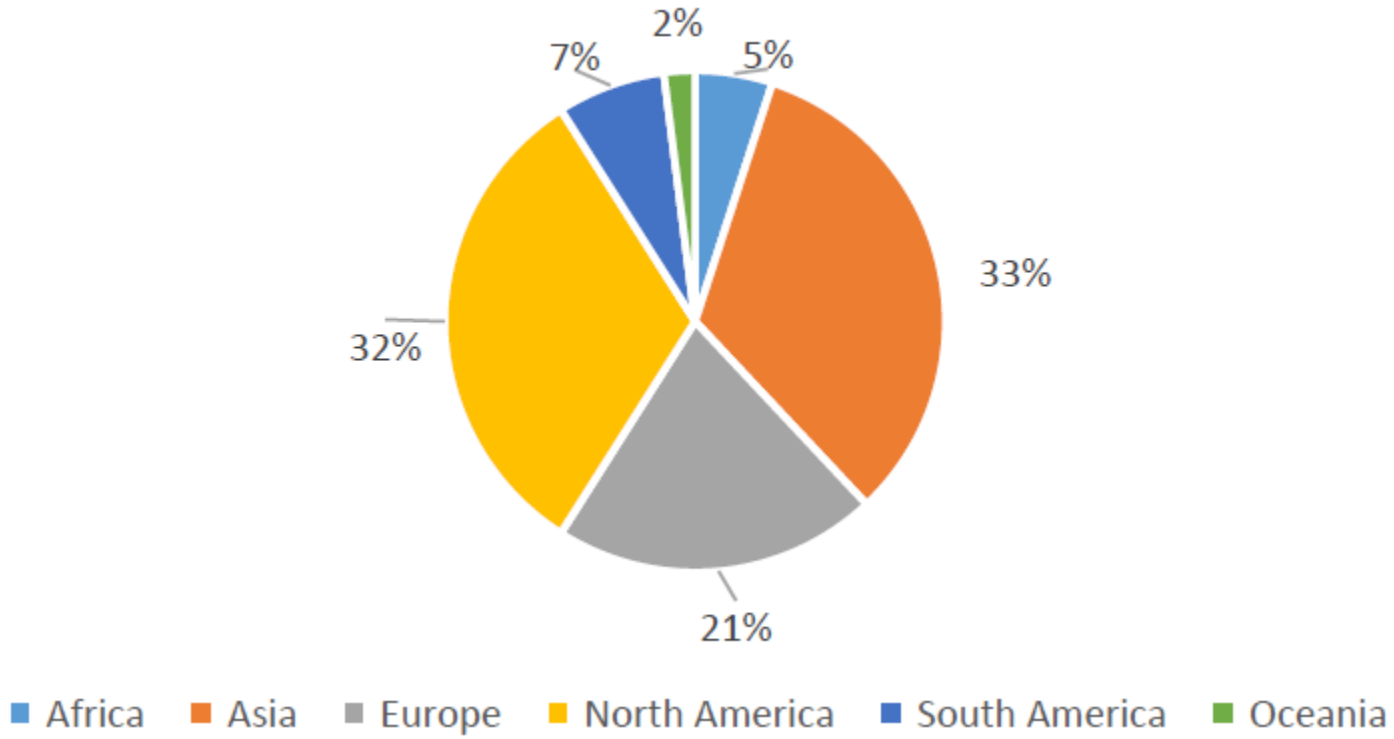
Algal MOOC #1 Age structure as Compared to All Coursera Courses



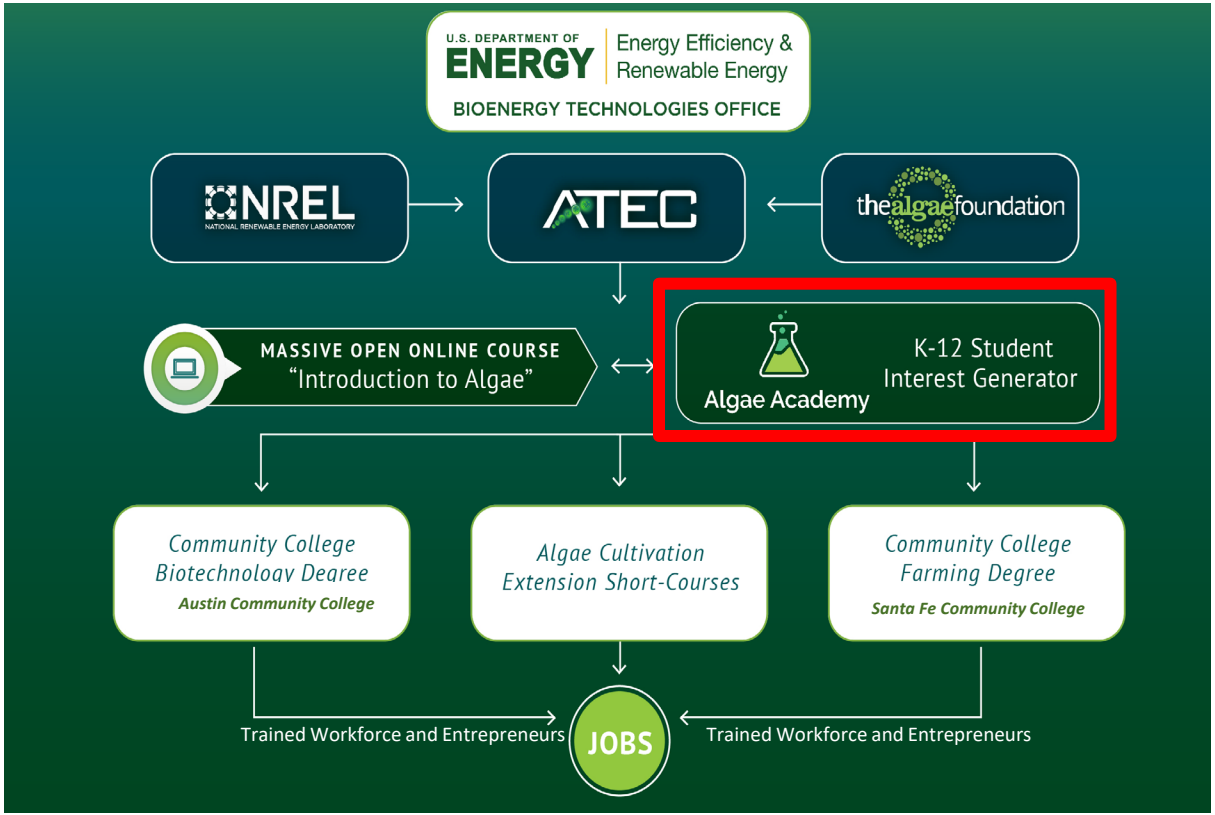
Algal MOOC #1 Educational Status



Algal MOOC #1 Student Geographic Distribution by Continent



Algal MOOC #1 Geographic Student Distribution as Compared to All Coursera Courses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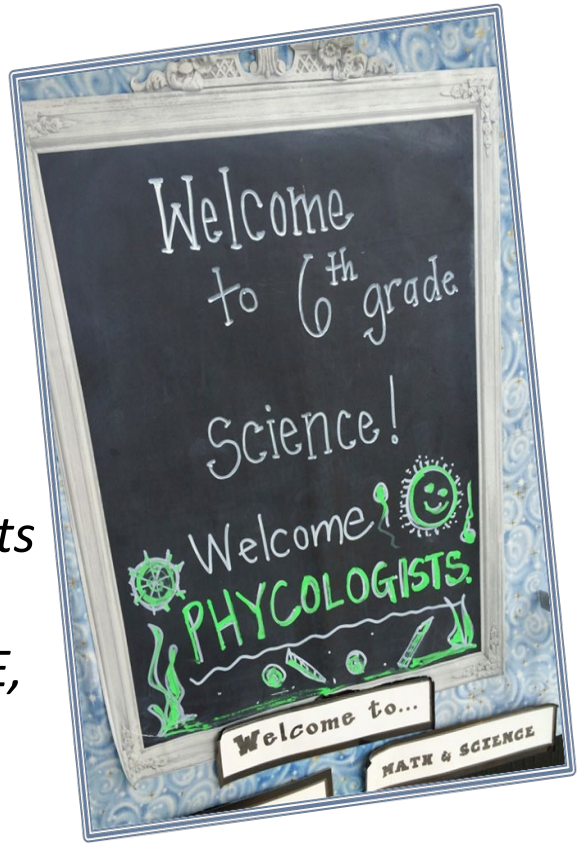
To educate & excite K-12 students on the Power of Algae

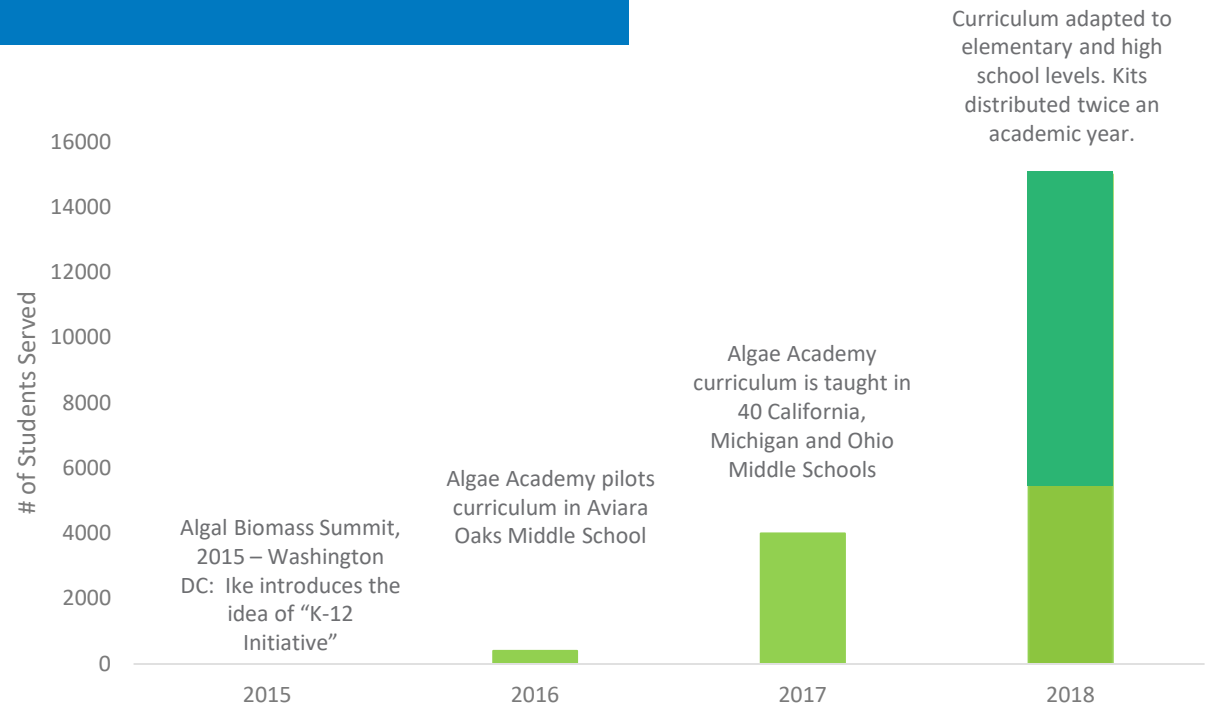
Algae Academy rollout
2017 ~5000 4th-11th grade students in CA, MI, OH
2018 ~ 20,000 students in CA, ME, MI, NM, OH, TX,



K-12 Initiative: The Kits and Curriculum

- 5-Day Curriculum
  - Uses of Algae
  - Cultivating Algae
  - Identifying Algae/Microscopy
  - Calculating Growth Rates
  - Algal Ecology & Environmental Extraction Services
- Kits are “drop-in” ready, delivered to the schools
- $250/kit – FREE to Schools
- 3-year Pledge

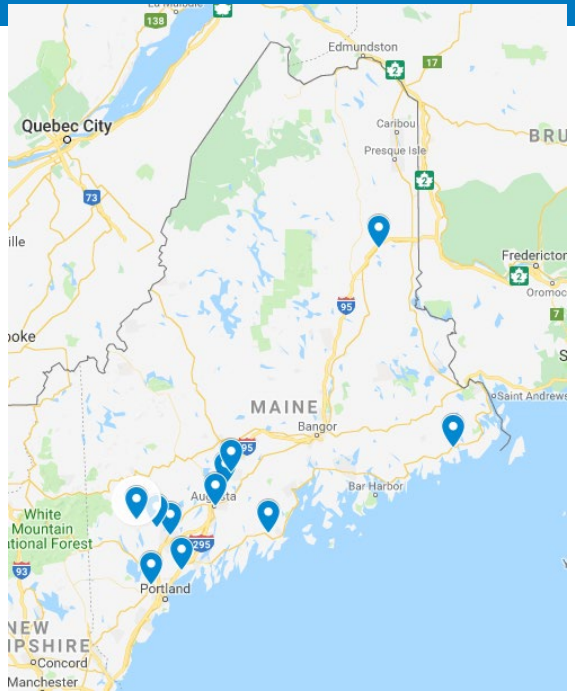
K-12 Initiative: History



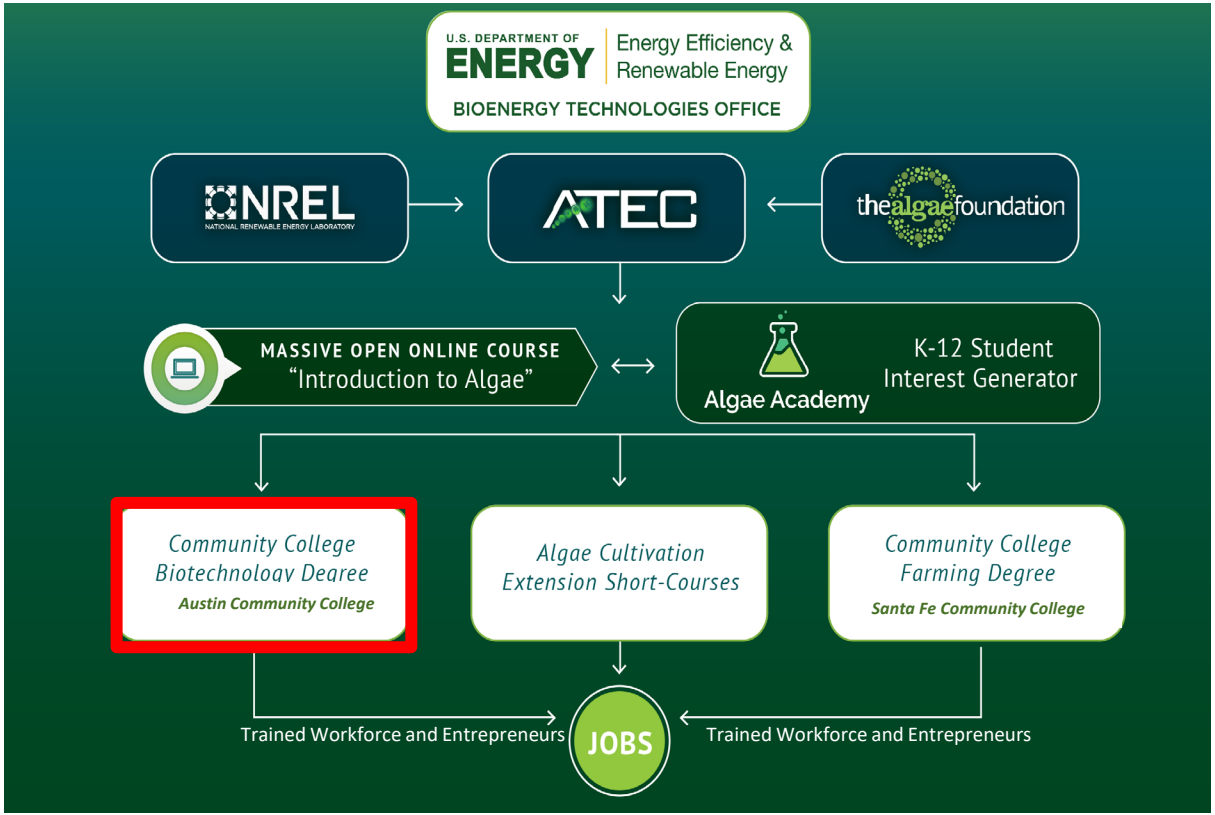
Algae Academy

Maine's Algae Summer Science Institute

- 5-day Science Institute
  - 2.5 Days Teaching the Teachers
  - 2.5 Days Teachers Teaching Students
  - Plenary Presentations
- Hosted by the University of Southern Maine
- 14 Maine Teachers
  - 5^{th}-11^{th} Grade
  - Acquire 4 Continuing Education Units (CEUs)
- 12 Students at the Institute
- ~1800 students Fall 2018



Algae Academy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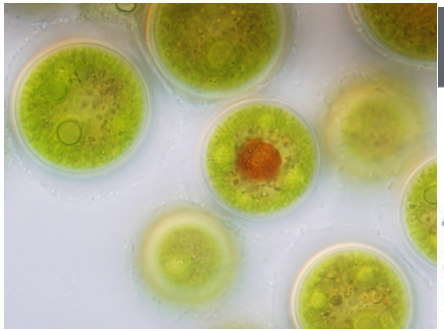
Algae Biotechnology @ Austin Community College and Beyond

Linnea Fletcher, ACC
Schonna Manning, UT-Austin



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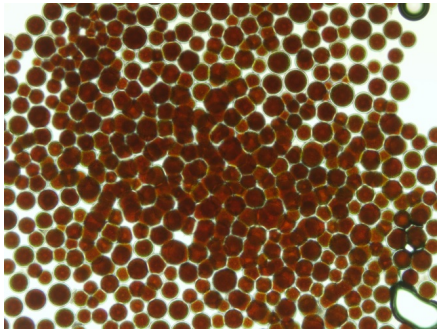
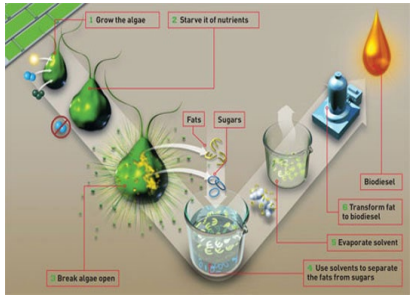
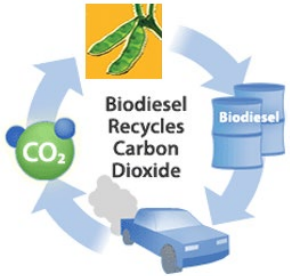


Algae in Biotechnology

Algae-to-Oil

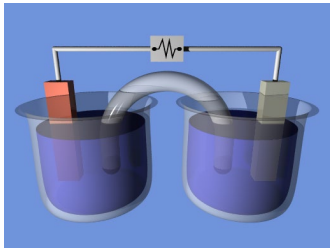


Oil-to-Biodiesel

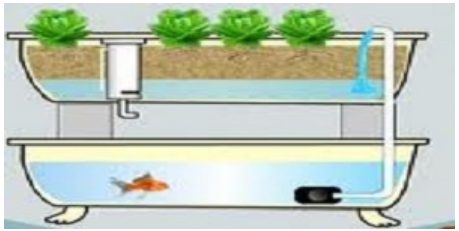


Biological Solutions for Life on Mars

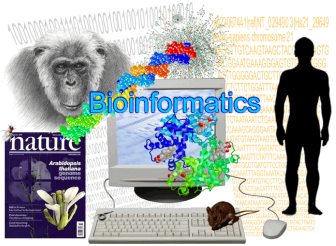
Microbial Fuel Cells



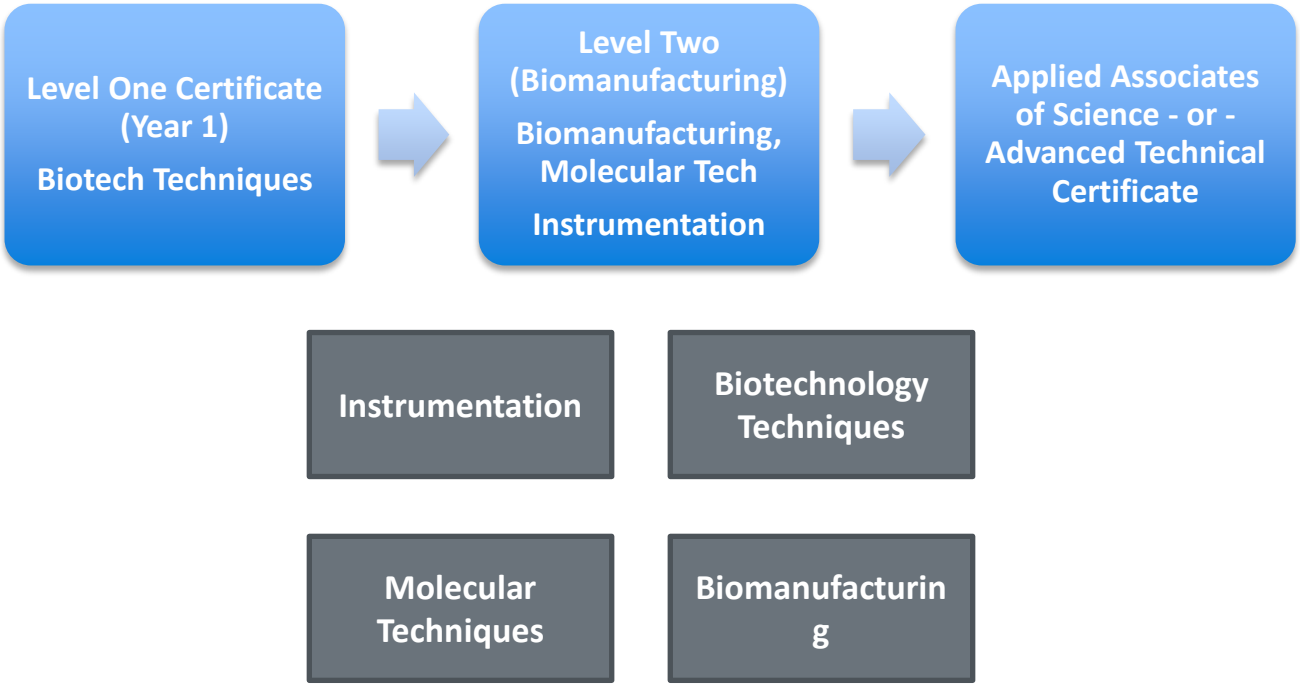
Aquaponics



Bioinformatics



ACC Biotechnology Degrees and Certificates



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Algae Technology Educational Consortium (ATEC)

Algae Biotechnology

Semester I

- BIOL 1414 Introduction to Biotechnology I

Semester II

- ***BIOL 1415 Introduction to Biotechnology II***
  RESEARCH PROJECT ON THE MANUFACTURE OF AN ALGAL PRODUCT
- BITC 1340 Quality Assurance

Semester III

- **BITC 2350 Bioinformatics (using sequences from BITC 2441) (new!)**
- ***BITC 2441 Molecular Techniques***
  DNA BARCODING LAB USING ALGAL STRAINS FROM UTEX
  (may not have enough time to do the bioinformatics)
- ***BITC 2411 Laboratory Instrumentation***
  TOTAL LIPID EXTRACTION
  TOTAL SAPONIFIABLE LIPIDS (FAME) ANALYSIS

Semester IV

- ***BITC 2431 Cell Culture Techniques (had to remove because of stem cell culturing needs)***
- ***BITC 1491 Special Topics in Biological Technology / Technician: BioManufacturing***
  MICROALGAE CULTURING METHODS: GROWTH KINETICS & BIOMASS METRICS

Semester V

- BITC 2487 Biotechnology Internship

BITC 2441
Laboratory Manual

Austin Community College, Biotechnology Dept.

Molecular Biology Techniques

TABLE OF CONTENTS

Algae Technology Educational Consortium (ATEC)

Algae Biotechnology

- **BITC 2350 Bioinformatics (online)**
  The Analysis of Algal Barcode Sequences lab will use data obtained from BITC 2441 to identify strains to the level of genus, and sometimes species using BLASTn, sequence alignments (CLUSTAL), and phylogenetic analysis

- **BITC 2411 Laboratory Instrumentation**
  The Analysis of Microalgal Lipids lab contains the following modules: lipid extraction, lipid class analysis by TLC, fatty acid derivatization to FAME, and quantitation of FAME using GCMS

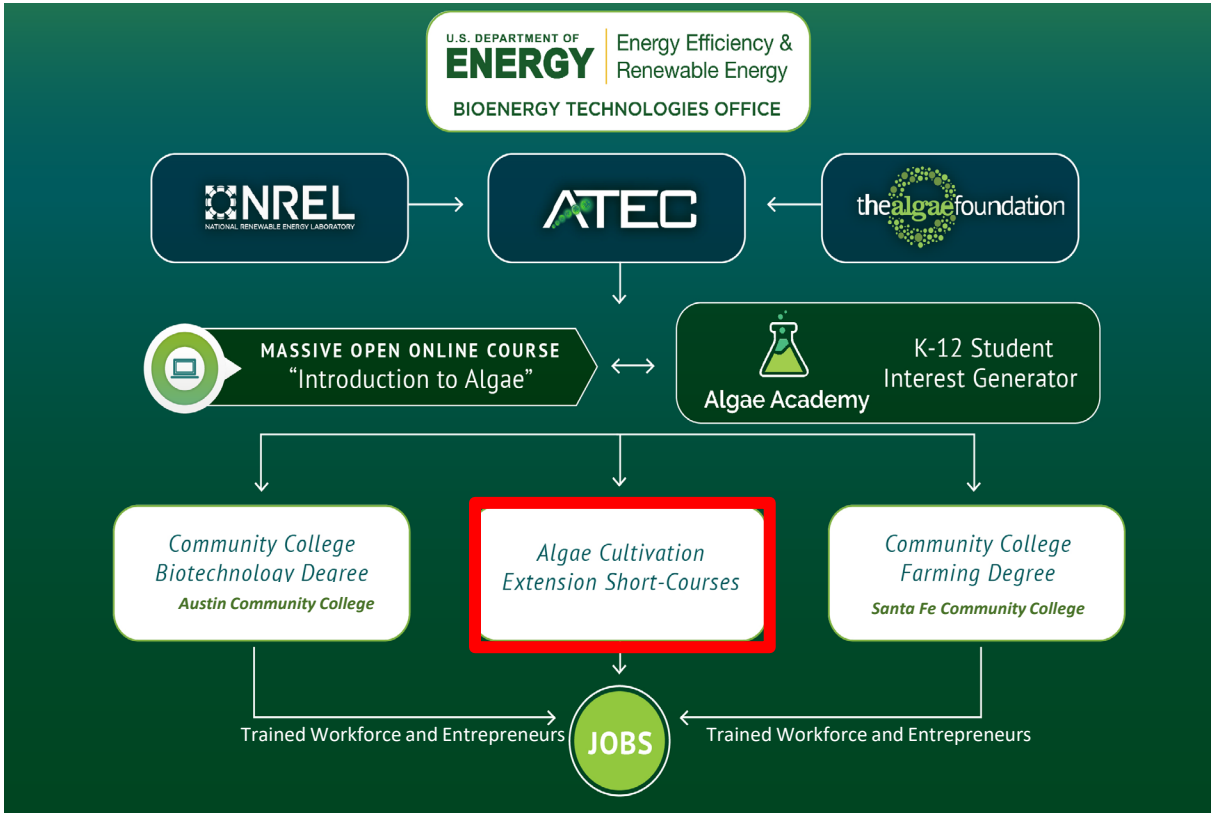
- **BITC 2431 Cell Culture Techniques**
  The Microalgal Culture Methods lab includes the following modules: media and vessel preparation, maintaining stock cultures and scaling up, growth kinetics and biomass metrics, i.e., hemocytometry (cells/mL), DW, AFDW, optical density (A680 and A750), and related calibration curves

- **BITC 2441 Molecular Techniques**
  The DNA Barcoding Lab Modules: genomic DNA extraction, PCR, gel verification, product purification, sequencing, and analysis

Algae Biotechnology Laboratory Intensive

Monday	Tuesday	Wednesday	Thursday	Friday
Culture Maintenance media preparation, sterile technique, microscopy, and spectrophotometry	Gravimetric Analysis wet weight, dry weight, ash-free dry weight, % moisture and % solids,	DNA Part I Isolation of DNA and RNA, PCR barcoding, and preparing samples for Sanger sequencing	DNA Part II gel electrophoresis, sequence analysis, and an introduction to bioinformatics	**Overview of Laboratory Skills - and - Lab Practical**
Genetic engineering I Plasmid construction, transformation	Genetic engineering II Plasmid construction, transformation, and screening	Biochemical Analysis I Total lipids, proteins, and carbohydrates, and analysis of lipids by TLC	Biochemical Analysis II Instrumentation and analysis of fatty acids and amino acids by GCMS	**Overview of Laboratory Skills - and - Lab Practical**

80 hours of content and training, 2 comprehensive lab practicals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Algae Cultivation Extension Short-courses (ACES) Part-1 Seaweeds

Aquaculture Introduction

- Overview: What is aquaculture, why is it important
- Dana Morse "What is Aquaculture?"
- International Mariculture of Seaweeds; An introduction to Seaweed Aquaculture. Dr. Charles Yarish
- From Sea to Table, University of Connecticut Research Benefits
- Seaweed Culture in New England: Overview of Seaweeds and Their Uses
- Seaweed in New England: A Seaweed Visionary. Interview with Shep Erhart, Maine Coast Sea Vegetables

Economically important species

- Seaweed culture in New England: Kelp, Gracilaria, Chondrus, Porphyra, Palmaria (Dulse), Kappyphycus and Eucheuma

Seaweed Aquaculture: Nursery

- Elements of a Seaweed Lab
- Introduction to Sugar Kelp Nursery Methods. University of New England

Seaweed Aquaculture: Leasing

- Permits/Leases/Regulations. Jon Lewis, Maine Dept. of Marine Resources

Seaweed Farm design and gear

- A Simple Method of Setting Seaweed Long Lines, Tollef Olson, President, Ocean's Balance

Outplanting seaweed seed :

- Field clips of outplanting seaweed lines with Maine Sea Farms

Seaweed Husbandry:

- Winter on a Kelp Farm, Ocean Approved

Seaweed Aquaculture: Farming

- Seaweed Farms of Maine
- Maine Sea Farms Explains Kelp Farming
- Seaweed Farming, Tollef Olson, Oceans Balance Inc.

Harvesting :

- Pulling Seaweed Lines (Ocean Approved)
- Harvesting Kelp with Maine Sea Farms, spring 2018

Seaweed Processing/marketing:

- Greenhouse drying of seaweed with Maine Sea Farms
- Seaweed Product Forms, Lisa Scali, Ocean Approved Inc

ALGAE TECHNOLOGY EDUCATIONAL CONSORTIUM

Published October 2019: ~ 395 students, 18 countries

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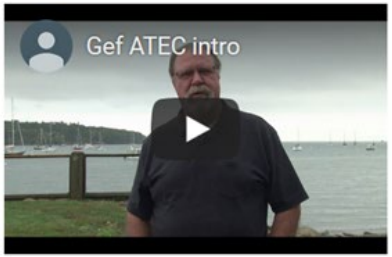
ACES PART 2: MICROALGAE

ACES > Part 1: Macroalgae > Part 2: Microalgae

Chapter 1: Introduction

http://www.algaefoundationatec.org/aces/aces2_micro.html



Time 0:58

Welcome to the Algae Cultivation Extension Short-Course: Gef Flimlin

Time 2:18

Welcome to the Algae Cultivation Extension Short-Course: Stephen M. Gómez

ACES PART 2: MICROALGAE COURSE CHAPTERS

Chapter 1

Introduction to microalgae

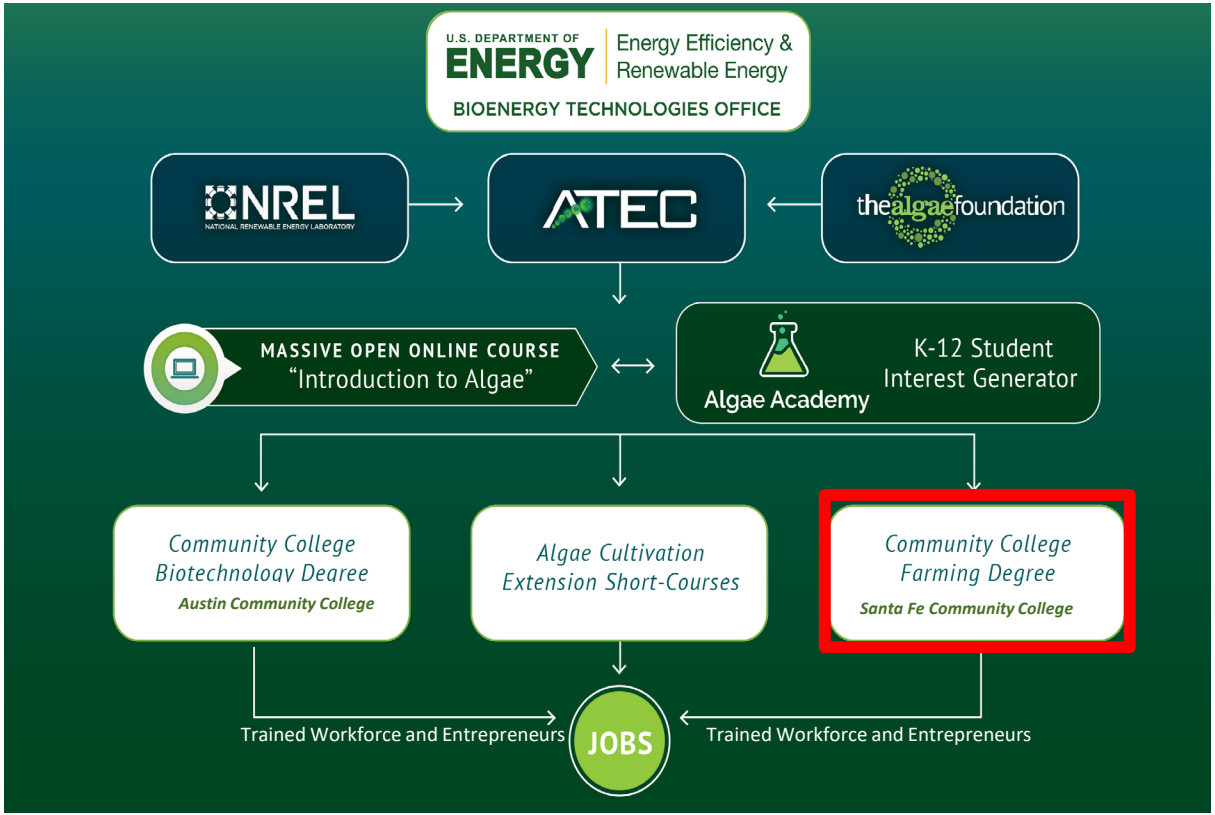
View chapter

Chapter 2

Chapter 3

Chapter 4

Chapter 5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Algae Technology Educational Consortium (ATEC)

Algae Cultivation

- ALTF 161 – Introduction to Algae Cultivation (+ online)
- ALTF 271 – Biology of Algae (+ online)
- ALTF 261 – Advanced Algae Cultivation (+ online)
- ALTF 262 – Algae Harvesting (+ online)
- ALTF 268 – Algae Capstone
- ALTF 298 – Biofuels Internship
- PLMB 141 – Pumps and Motors (+ online)
- WATR 166 – Microbiology for Water Operators

- BLDG 111 – Construction Safety

NEW COURSES

ALGE 111 – Introduction to Algaculture
ALGE 211 – Advanced Algaculture
ALGE 221 – Algae Harvesting & Processing
ALGE 298 – Algaculture Capstone
MOOC - Introduction to Algae

BIOL 252 – Algae Biotechnology 1
BIOL 250 – Introduction to Algal Science
BIOL 253 – Algae Bioprospecting Informatics
PLMB 141 – Pumps and Motors

LEARNING OUTCOMES AND SKILL SETS for each class and program as a whole

		ALTF 161	ALTF 261	ALTF 262	ALTF 268 ALTF 298	PLMB 141	BIOL 111	BIOL 111L	WATR 166	ALTF (Phyc)	Bioinfomatics	BLDG 111	Short course
1	Media preparation	x	x					x	x				x
2	Sterile technique	x	x					x	x				x
3	Microscopy	x	x					x	x				x
4	Culture inoculation	x	x					x	x				x
5	Scale up: colony to 10L	x											x
6	Scale up: 10L to >500L		x										x
7	Monitoring procedures for biomass analysis	x	x	x					x				x
8	Lab and farm safety	x	x	x		x			x			x	x
9	Operations and maintenance	x	x	x		x			x				x
10	Harvesting operations			x					x				x
11	Biomass analysis and quality assessment		x	x					x				x
12	Biomass storage techniques		x	x									x
13	Heterotrophic growth and fermentation		x	x					x	x			x
14	Algae identification	x	x	x					x	x			x
15	Pathogen/predator identication	x	x	x					x				x
16	Treated wastewater utilization		x	x					x				x
17	Quality control analysis	x	x	x					x				x
18	Data collection and analysis	x	x	x				x	x				x
19	Internship				x								
20	Pump and motor operations					x			x				
21	Hydraluic sizing					x							
22	Electrical demand requirements					x			x				
23	Mechanical properties of water					x			x				

Algae Technology Educational Consortium (ATEC)

CERTIFICATE IN ALGAE CULTIVATION

Core Requirements

CORE REQUIREMENTS: (32 HRS. MIN.)
ALTF 161 Introduction to Algae Cultivation (3)
ALTF 261 Advanced Algae Cultivation (3)
ALTF 262 Algae Harvesting (3)
ALTF 268 Algae Capstone (1-3)
[or]
ALTF 298 Biofuels Internship (1-3)
BLDG 111 Construction Safety (3)
ENVR 112 Introduction to Sustainable Energy Technologies (3)
GRHS 121 Greenhouse Operation and Management (4)
HRMG 118 Sanitation and Safety (2)
PLMB 141 Pumps and Motors (2)
WATR 160 Applied Chemistry for Water Treatment Operators (4)
WATR 166 Microbiology for Water Treatment Operators (4)

First Year Student Success (3 hr.) If required — See NOTE
STEM 111 Introduction to Science, Technology, Engineering and Mathematics (3)
NOTE: See First-Year Student Success Course Requirement on Page 8.

TOTAL 32 CREDITS MIN.

Algae Technology Educational Consortium (ATEC)

CERTIFICATE IN ALGAE CULTIVATION

CERTIFICATE IN
ALGAE CULTIVATION
(32 hrs. min.) CIP: 01.0301
School of Trades, Advanced Technologies and Sustainability, 505-428-1664

This program covers the basic science and technology of algae cultivation. This certificate provides students with the skills required to work in the algae cultivation (algaculture) industry or create their own algaculture business. Students will learn the controlled environment requirements for successful cultivation of various algae species. The program emphasizes training in algal cultivation technologies, including algaculture extension training. Knowledge acquired will prepare students for jobs as Greenhouse/Agricultural Workers, Plant Technicians, Plant Managers, Laboratory Technicians, Sales Managers, Public Relations and Outreach, Process Coordinators, Extension Service and/or Business Owners/Managers.

Students can earn the following degree related to this certificate:
• A.A.S. Controlled Environment Agriculture

PROGRAM LEARNING OUTCOMES
Upon completion of this program, students will be able to:
• Create and maintain a safe working environment.
• Design, install, maintain and operate sustainable algaculture systems.
• Identify wasteful practices and recommend sustainable alternatives.
• Measure and describe energy and its relationship to sustainable systems.
• Articulate the principles of entrepreneurship and creating a sustainable small business.

SFCC Approach

Intro to Algae Cultivation
- Basic biology
- Basic chemistry
- Scientific method
- Algae cultivation –
  - Colony isolation to 10 L PBR

Adv. Algae Cultivation
- Adv. Analytical Tech.
- Data Collection
- Data analysis
- Algae cultivation –
  - 10 L PBR to >500 L PBR

Algae Harvesting
- Harvesting Tech.
- Value-added products
- Quality control
- Algae Project –
  - Algae farm proposal

Algae Internship
- Internship with business.
- Independent research projects

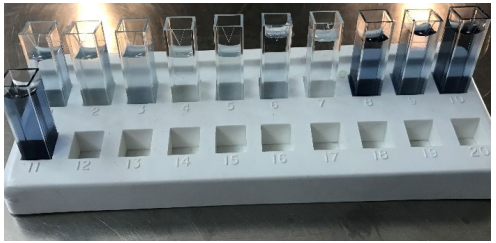
ALTF 161 – Introduction to Algae Cultivation → ALTF 261 – Advanced Algae Cultivation → ALTF 262 – Algae Harvesting → ALTF 268 – Algae Capstone / ALTF 298 – Biofuels Internship

Pumps and Motors
- Pump technologies
- Pump sizing
- Troubleshooting
- Basic electric motors

PLMB 141 – Pumps and Motors

Safety
- OSHA 30-hour safety course

BLDG 111 – Construction Safety



Plant-based Biology
- Introductory Biology Plant/algae cells and Photosynthesis

BIOL 111/L Intro Biology

Prerequisites
- ENGL 109
- MATH 102

PLAN B

Aquatic Microbiology
- Microbiology of water systems

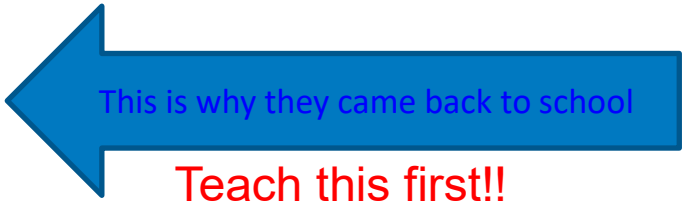
WATR 166 – Microbiology for Water Treatment Operators

LEARNING OUTCOMES AND SKILL SETS for each class and program as a whole

		ALTF 161	ALTF 261	ALTF 262	ALTF 268 ALTF 298	PLMB 141	BIOL 111	BIOL 111L	WATR 166	ALTF (Phyc)	Bioinfomatics	BLDG 111	Short course
1	Media preparation	x	x					x	x				x
2	Sterile technique	x	x					x	x				x
3	Microscopy	x	x					x	x				x
4	Culture inoculation	x	x					x	x				x
5	Scale up: colony to 10L	x											x
6	Scale up: 10L to >500L		x										x
7	Monitoring procedures for biomass analysis	x	x	x					x				x
8	Lab and farm safety	x	x	x		x			x			x	x
9	Operations and maintenance	x	x	x		x			x				x
10	Harvesting operations			x					x				x
11	Biomass analysis and quality assessment		x	x					x				x
12	Biomass storage techniques		x	x									x
13	Heterotrophic growth and fermentation		x	x					x	x			x
14	Algae identification	x	x	x					x	x			x
15	Pathogen/predator identication	x	x	x					x				x
16	Treated wastewater utilization		x	x					x				x
17	Quality control analysis	x	x	x					x				x
18	Data collection and analysis	x	x	x				x	x				x
19	Internship				x								
20	Pump and motor operations					x			x				
21	Hydraluic sizing					x							
22	Electrical demand requirements					x			x				
23	Mechanical properties of water					x			x				

Stealth STEM

- Students re-entering the community college system DO NOT want an “education”
- They want a good-paying stable JOB!!!!!
- The traditional academic system does not serve their needs:
- Traditional order in college programs:
  1. General education courses
  2. Core courses
  3. Specialized courses
  4. Degree



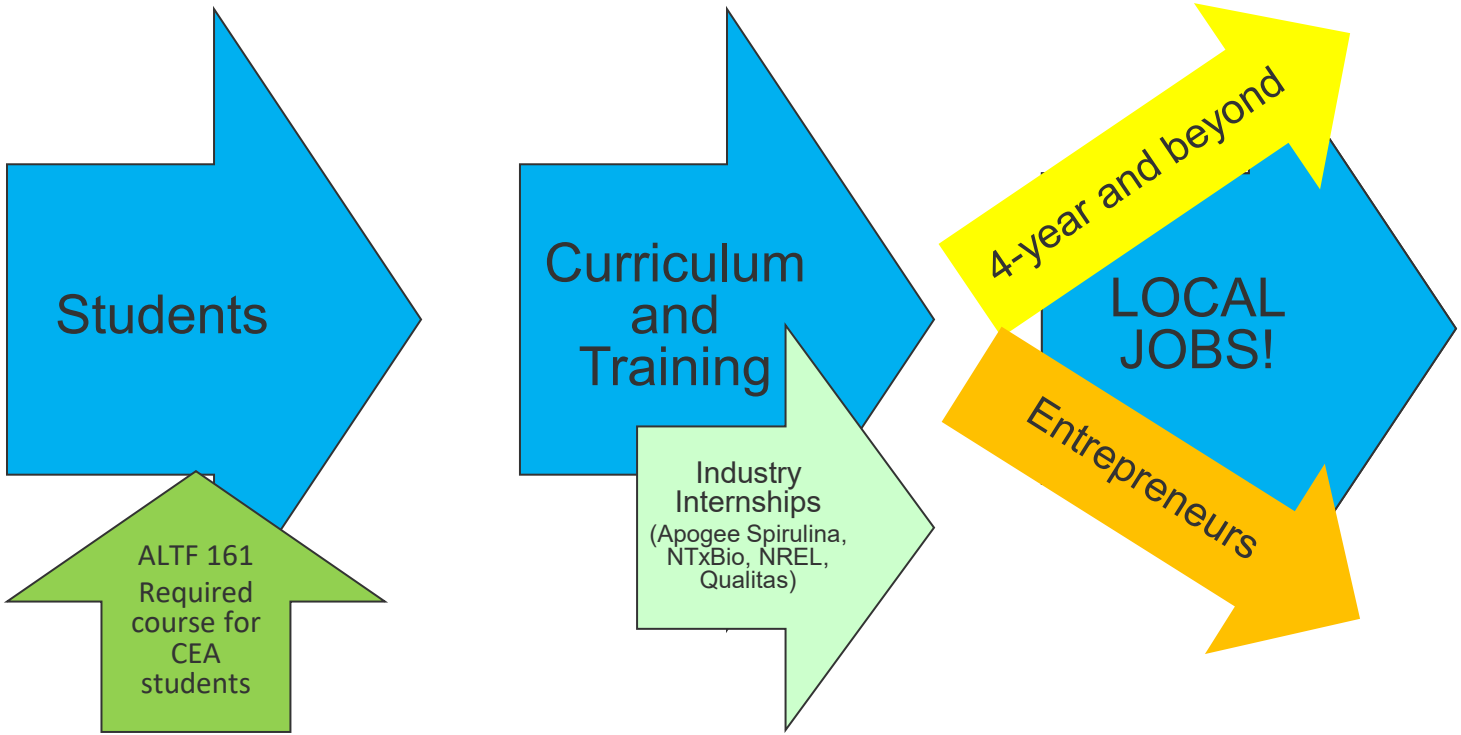
Stealth STEM

1st Semester

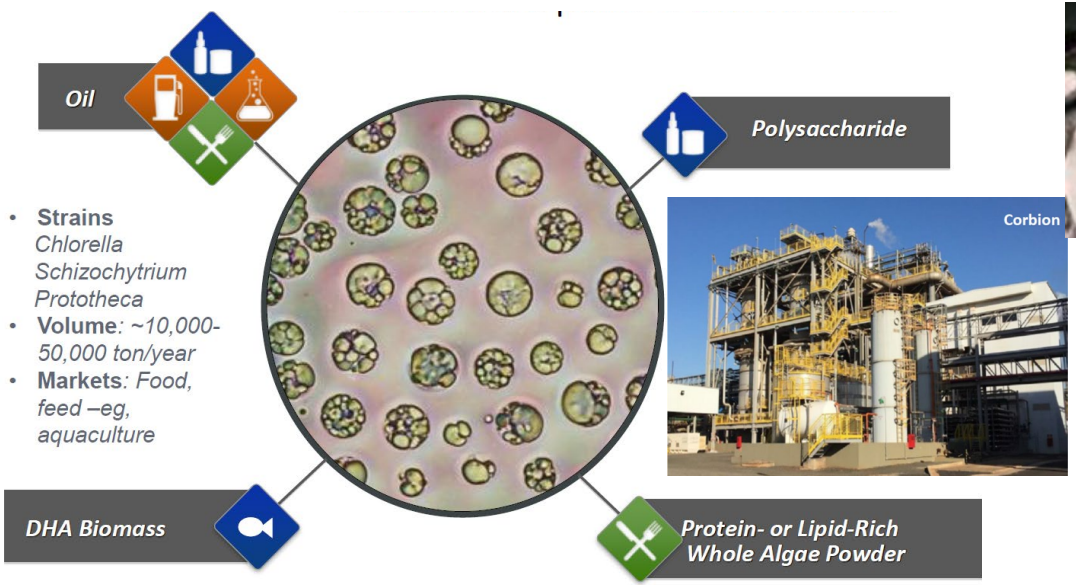
- New students
  - "I don't need biology to learn how to grow algae"
  - "I can't do math"
  - "Why do I need chemistry? I just want to grow plants."
- Put the students in the lab
- Let them work on the topics they came back to school to learn
- Give them enough rope to hang themselves

2nd Semester

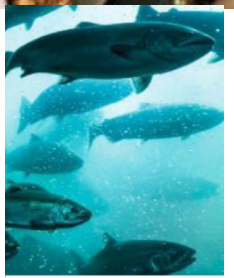
- Continuing students
  - "Dr. Gómez, the chemistry class is full. What do I do?"
- Students who "discover" they need STEM courses do much better than students who are "told" they need STEM courses
- Paid internships are the best retention tool
  - "You mean I can get paid to do this?"


Students
ALTF 161
Required course for CEA students
Curriculum and Training
Industry Internships
(Apogee Spirulina, NTxBio, NREL, Qualitas)
4-year and beyond
LOCAL JOBS!
Entrepreneurs

New Curriculum: Heterotrophic Algae Cultivation



- **Strains**
  Chlorella
  Schizochytrium
  Prototheca
- **Volume**: *~10,000-50,000 ton/year*
- **Markets**: *Food, feed –eg, aquaculture*



Fish oil ~ $2/kg

High volume
Lower value
products