Aquaponics Engineering

BE 444/544 (3 units)

[Tues/Thurs - Spring]

Description of Course

This course begins with an overview of aquaponics – the culture of fish and plants together – and then provides an in depth guide into properly designing, building and troubleshooting aquaponics systems, especially on the commercial scale. Engineering aspects of aquaponics systems will be thoroughly discussed in addition to biochemical processes, filtration and designing for various flow rates, fish species and plants. The course provides students with numerous hands-on learning activities and offers students the opportunity to advance their knowledge of aquaponics well beyond the basics. Typically offered: Spring.

Course Prerequisites or Co-requisites

Advanced standing in Engineering, BE 334 (Aquaponics Design) or instructor approval required
Math 111 and Math 112 are recommended
CE 218 (Fluid Dynamics) or equilvalent is also recommended

Instructor and Contact Information

Dr. Matthew "Rex" Recsetar, Office at CEAC, cell:(847) 814-2741, msrecs@email.arizona.edu

Office Hours: 10:00 am-Noon Tues, Thurs or by appointment

Course homepage: https://d2l.arizona.edu/d2l/home/593665

Course Communications

Students can communicate with the instructor through email (msrecs@email.arizona.edu), or D2l Discussion board

Course Format and Teaching Methods

The course will consist of lectures, videos, readings and interactive activities. The class will be taught in somewhat of a flipped format as many of the lectures will be completed outside of class hours with in-class time devoted to more hands-on activities, group work and discussion. Bi-weekly discussion posts will be required. There will also be multiple group activities, one of which will be a final design project of a commercial aquaponic system. There will also be short quizzes at the beginning of each class to assess participation. In addition, students will be required to complete extracurricular activities, most of which will be completed during class hours but will have options for students to do on their own time.

Course Objectives and Expected Learning Outcomes

Course Objectives

This course will

1. Emphasize engineering principles pertaining to successful aquaponics designs.

2. Familiarize students with microbiomes present in aquaponics systems.

3. Discuss different types of aquaponics systems, its components and how they can be designed to optimize the engineering.

4. Demonstrate techniques, skills and tools necessary for building, designing and running advanced aquaponics systems of various size and scope

Student Learning Outcomes

By the end of the semester, students will be able to:

1. Thoroughly **describe** what aquaponics is and **explain** how and why it works.

2. **Identify** and **select** the optimal design parameters for an aquaponic system based on growing specific plants/crops.

3. **Develop** a framework of the various building components, sensors and controls that are needed to fabricate successful, turn-key aquaponics systems and estimate their costs

4. **Discuss** the role aquaponics will play in the future of food.

5. **Design** and **build** a small-scale aquaponics system.

6. **Design** a commercial aquaponics system

7. **Complete** an energy balance for an aquaponics system (Grad students only)

8. **Create** a biosecurity plan for a commercial aquaponic system (Grad students only)

Required Texts or Readings

[There is no required text for this class]

1. Recsetar, M. & Kelly, A. 2015. *Is Aquaponics for you? Realities and Potentials for Arkansas*. University of Arkansas Cooperative Extension Service FSA 9618. 6 pp.

2. Rakocy, J., Losordo, T. & Masser, M. 1992. *Recirculating Aquaculture Tank Production Systems. Integrating Fish and Plant Culture.* SRAC Publication No. 454. 8 pp.

3. Tyson, R.V., Treadwell, D.D., Simonne, E.H. 2011. *Opportunities and challenges to sustainability in aquaponic systems.* Horttechnology, 21 pp. 6-13

4. Love, D.C., Uhl, M.S., Genello, L., 2015. Energy and water use of a small-scale raft aquaponics system in Baltimore, Maryland, United States. Aquaculture Engineering 68 pp 19-27.

5. Goddek S et al. 2015. *Challenges of Sustainable and Commercial Aquaponics*. Sustainability vol. 7 no. 4, pp. 4199-4224

6. Eck, M., Sare, A.R., Massart, S., Schmautz, Z., Junge, R., Smits, T.H.M., Jijakli, M.H., 2019. *Exploring bacterial communities in aquaponic systems*. Water (Switzerland) 11, pp 1-16.

7. Kyaw, T.Y., Ng, A.K., 2017. *Smart Aquaponics System for Urban Farming*. Energy Procedia 143, 342-347.

8. Mamatha, M.N., Namratha, S.N., 2018. *Design & implementation of indoor farming using automated aquaponics system*. 2017 IEEE International Conference on Smart

Technologies and Management for Computing, Communication, Controls, Energy and Materials. Proceding 2 pp 396-401.

9. Mandap, J.P., Sze, D., Reyes, G.N., Dumlao, S.M., Reyes, R., Yaw, W., Chung, D., 2018. Aquaponics pH Level, Temperature, and Dissolved *Oxygen Monitoring and Control System Using Raspberry Pi as Network Backbone*. TENCON 2018 – 2018 IEEE Reg. 10 Conf. 1381-1386.

10. Goddek S, Espinal CA, Delaide B, Jijakli MH, Schmautz Z, Wuertz S, Keesman KJ. 2016. *Navigating towards decoupled aquaponic systems: a system dynamics design approach*. Water 8:303

11. Delaide, B., Delhaye, G., Dermience, M., Gott, J., Soyeurt, H., Hihakli, M.H., 2017. Plant and fish production performance, nutrient mass blanaces, energy and water use of the PAFF Box, a small-scale aquaponic system. Aquaculture Engineering 78 pp 130-139.

Optional and Recommended Readings

1. Jacob, N.K., 2018. *IoT powered portable aquaponics system*. 1-5.

2. Delaide, B., Goddek, S., Gott, J., Soyeurt, H., Hihakli, M.H., 2016. Lettuce (Lactuca sativa L. var. Sucrine) growth performance in complemented aquaponic solution outperforms hydroponics. Water (Switzerland) 8, pp 1-11.

(PDF links will be provided for the above articles in D2L)

Good reference book:

- Reciruclating Aquaculture by Timmons and Ebeling

Required or Special Materials

Parts for mini-aquaponics systems and labs will be provided by the instructor ($50 cost)

Required Extracurricular Activities (Graduate Students Only)

Extracurricular activities: the following activities must be completed by graduate students:

- Visit the Biosphere 2 (Write a one to two page essay on how aquaponics fits into the future of food)
- Develop a biosecurity plan for a commercial aquaponics operation
- Create an energy balance for your group's aquaponics system
- Come up with a potential innovation that could help with the commercialization of aquaponics and discuss how it could be implemented.

*Specific direction and rubrics for the assignments will be posted in the content area of D2L.

Assignments and Examinations: Schedule/Due Dates

Exams will be taken in class on the assigned day unless other arrangements are made with the instructor. 2 hours will be allowed for exams, which will consist of multiple choice, short answer and fill in the blank questions.

There will be 5 discussion posts required that relate to course material, and we will go over discussions during class where interaction will take place.

*Specific direction and rubrics for the assignments will be posted in the content area of D2L.

Your course grade will be based on Exams and quizzes, group projects, participation in discussions, attendance and completion of system building labs.

Assignment	Value (undergrad)	Value (Grad)
Exams (2 @ 100)	200	200
Group Build Project	100	100
Final Group Design project	100	100
Discussion Posts (5 @ 15)	75	75
Reading Quizzes (10 @ 10)	100	100
Labs (10 @ 10)	100	100
Attendance (25 @ 1)	25	25
Grad student projects (4 @ 25)		100
Total	**700**	**800**

Final Examination or Project

The final project will consist of you and your group developing plans for a commercial-scale aquaponic system of your design. Groups will collaborate both in and out of class, and develop a complete blueprint of the system with all associated costs, parts and equipment. I will closely follow the progress of each group and offere guidance as needed. The design blueprint can be done in AutoCAD, Sketch-up or Solid Works. Up to 15 points extra credit will be given to groups that build a physical model. Each project will be presented at the end of the semester in front of the class.

The final project will be in lieu of the final exam.

*Specific direction and rubrics for the assignments will be posted in the content area of D2L.

Grading Scale and Policies

DETERMINATION OF CLASS GRADES:

Score	Grade
90-100% (630-700)	A
80-89% (560-629.9)	B
70-79% (490-559.9)	C
60-69% (420-489.9)	D
Below 420	E

GRADE DEFINITIONS

A: Achievement that is outstanding relative to the level necessary to meet course requirements.
B: Achievement that is significantly above the level necessary to meet course requirements.
C: Achievement that meets the course requirements in every respect.
D: Achievement that is worthy of credit even though it fails to fully meet the course requirements.
E: Represents failure (no credit) and signifies that the work was not worthy of credit or was not completed.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Dispute of Grade Policy
Students will have one week to dispute a grade on a project, quiz or exam.

Scheduled Topics/Activities

List topics in logical units in a weekly/daily schedule, including assignment due dates and exam dates.

Module	Date	Day	Lecture or Lab Topics	Required Readings or Discussions Due	Online Videos, lectures & Assignments
1	1-16	R	Class Overview Introduction to Aquaponics	Discussion 1 Reading 1 (Recsetar and Kelly)	Introduction to Aquaponics
	1-21	T	Floating Raft Systems	Reading 2 (Rakocy et al.)	
	1-23	R	Lab 1: Field Trip to Merchant's Garden		Working with PVC
	1-28	T	Media Bed Systems		Bell Siphons
	1-30	R	Lab 2: PVC & Bell Siphons		
	2-4	T	NFT Systems Visit Amhydro greenhouse	Reading 3 (Tyson et al.)	NFT Systems
2	2-6	R	Filtration (Group Project 1 Assigned)	Reading 4 (Love et al.) Ebeling & Vinci (optional)	Filters; Clarifier-biofilter Build; Swirl Filter
	2-11	T	Lab 3: Group Project Work Day 1 – System Design	Discussion 2: Which system would you choose and why? Reading 5 (Goddek et al.)	Selecting and Gathering Materials
	2-13	R	Lab 4: Group Project Work Day 2 – Gathering Parts	Design Blue Print	Selecting the Appropriate Systems
	2-18	T	Aeration		Aeration
	2-20	R	Lab 5: Building and Sizing Filters		Building a Swirl Filter
	2-25	T	Aquaponic System Microbiomes	Reading 6 (Eck et al.)	Aeration
	2-27	R	Lab 6: Group Project Work Day 3 -System Build	Discussion 3: Which type of system is cheapest and/or most efficient for commercial production?	Plumbing Guides 1 and 2
	3-3	T	EXAM 1 (Modules 1,2)		
3	3-5	R	Group Presentations (Group Project 1 Due)		
	3-10	T	Spring Break	NO CLASS	
	3-12	R	Spring Break	NO CLASS	
	3-17	T	Pumps and Pump Curves (Group project 2 Assigned)	CLASS CANCELED	
	3-19	R	Pressure and Flow, (and Sizing pumps)	Quiz 6- Biofiltration	Sizing Your Pump
	3-24	T	Water Quality and Fish	Quiz 7 – Pressure and Flow	

			Care		
	3-26	R	Probes, Sensors and Controls Lab 8: Cleaning & Organizing Greenhouse	Readings 7, 8 and 9 Discussion 4: Which parameters are the most important to control in an aquaponics system?	Arduino-based Aquaponics; Controls in Aquaponics
4	3-31	T	Decoupled Aquaponics	Reading 10 (Goddek et al. 2)	Innovation in Aquaponics
	4-2	R	Lab 9: Final Project Planning	Quiz 9 – Probes, sensors and controls	
	4-7	T	Mass Balances and Loading	Quiz 10 - Decoupled Aquaponics Reading 11 (Delaide et al.)	
	4-9	R	Lab 10: Project Work Day – Commercial Design		
	4-14	T	Energy Balances	Quiz 11 – Mass and Energy Balances	
	4-21	R	EXAM 2 (Modules 3,4)		
5	4-16	T	Pest Control and Management	Discussion 5: What are the most common and difficult issues that arise when operating aquaponics systems	Insects and Pests
	4-23	R	Upkeep and Troubleshooting		System Maintenance
	4-28	T	Lab 12: Upkeep and Troubleshooting Lab		
	4-30	R	Final Project Work Day		
	5-5	T	GROUP PRESENTATIONS	Discussion 6 (If needed)	

Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/absences

Participating in the course and attending in-person lectures and labs is crucial to learning in this class. In addition, online lectures and other course events are vital to the learning process. As such, attendance is required, and more than 3 unexcused absences will result in being dropped from the course. Students who miss quizzes or exams due to illness or emergency are required to bring documentation from their health-care provider or other relevant, professional third parties. Failure to submit third-party documentation will result in a zero on the quiz. Labs can be

made up for credit if prior arrangements are made with the instructor.

Makeup Policy for Students Who Register Late

Since this is a 5-week summer course, students will only be allowed to miss the first 3 days due to late registration. These students will be allowed to complete past assignments as deemed appropriate by the instructor.

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

At the University of Arizona we strive to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, you are welcome to let me know so that we can discuss options. You are also encouraged to contact Disability Resources (520-621-3268) to explore reasonable accommodation. For additional information on the Disability Resource Center and reasonable accommodations, please visit http://drc.arizona.edu.

If our class meets at a campus location: Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://www.library.arizona.edu/help/tutorials/plagiarism/index.html.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Student Assistance and Advocacy information is available at http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-

act-1974-ferpa?topic=ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.