Integrating Biological Engineering Senior Design and Aquacultural Entrepreneurship: Case Study of Development of a Mobile Scalable Oyster Hatchery

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Abstract

ASEE SE 2019 Abstract, Submission ID 39

This project was focused on the intersection between Engineering Senior Design and entrepreneurship as applied to a portable oyster hatchery. Engineering curricula have included a capstone or "Senior Design" course for decades. Under ideal circumstances, an industry sponsor provides both input on engineering constraints and some kind of technical and resource support. This has included an entrepreneurial aspect de facto in some cases. In the last two years, the NCSU College of Agriculture and Life Sciences has instituted an Agricultural Entrepreneurship course series. In the present project, four students in a Biological Engineering curriculum senior design course collaborated with a senior in the Agricultural Entrepreneurship course to focus on both the business and engineering aspects of a unique but growing market segment: shellfish aquaculture.

Engineering design for this project included optimizing flow for "steady state" and larval growth conditions; focus on optimizing conditions for early life stage including use of materials for optimal spat set; and optimizing the system for light weight, low energy applications. The system was also designed for mounting on a trailer and scaled for larger portable applications. Significant intersection between the economics, business, biological and engineering aspects of the project helped with a "design-build" type approach.

The NCSU Agribusiness Entrepreneurship student employed Lean Startup methods and traditional financial projections to evaluate the design. Lean Startup methods include research on existing markets and industry operations to determine how this novel technology can be implemented at various scales and what revenues, costs, and risks may demonstrably be expected.

The engineering team used scalable modular techniques and focused on a limited number of relevant parameters including salinity, flow rate, energy usage, physical/geometric configuration, water quality and feeds to design an optimized portable scalable system. This system is designed for a trailer but can be scaled to larger portable designs. This allows operators to service multiple clients; while also minimizing liability in the case of storm surge or other challenges. Overall, the design is cost effective, environmentally friendly and economically sensible, based

on both engineering optimization and sound business techniques. Finally, the experience for the students and sponsors enhanced understanding and impact, allowing students to learn about entrepreneurship and business; while sponsors were able to interact with students and consider them as potential employees, collaborators or partners, enhancing both learning objectives and business impact.

Keywords

Aquaculture; oyster; hatchery; business model; entrepreneurial engineering

Introduction

Oyster production and the overall shellfish industry have been growing. Those involved in this business need to consider the biology of the system, as well as business and technical aspects of culture as they engineer and design systems to support the industry. Although oysters have been considered a prized delicacy for centuries[1] their value has risen and, especially on the east coast of the US, the oyster market and the culture of oyster has grown in recent years. Worldwide, shellfish are a significant source of protein for the growing world population[2]. This exciting arena can be a place to apply engineering and entrepreneurial techniques, which might further enhance market, food safety and water quality while enhancing efficiency and sustainability. Applying engineering entrepreneurship to Senior Design within this context is one potential way to enhance both learning and value[3,4]. A number of researchers have considered how entrepreneurship can enhance engineering skills and education, and such integrated projects could be a relevant way to apply these techniques[5,6]. Some studies have even suggested that adding an entrepreneurial aspect to engineering projects might enhance GPA and retention as well as other engineering education objectives[7].

This consideration of complementarity between education, entrepreneurship and engineering was also reflected in the diverse approaches to the technical challenges in this project. On the technical side, both engineering and biology were considered. Oysters are filter feeders and naturally form reefs that can provide habitat, clean the water and protect the coast. They are also part of the fast growing aquaculture industry which helps provide high quality protein to the growing world population[8,9,10]. Methods to grow oysters in aquaculture have included long line systems, on bottom culture and rack type culture[11,12]. The present work focused on a critical part of aquaculture: reproduction. Specifically, hatchery production of larval oysters is necessary for a growing industry. Ideally, hatcheries would be located near the growout areas - often low lying coastal areas - to supply growers. However, since there is some investment in capital, there have been to date a limited number of hatcheries. The current project focused on developing a portable hatchery system capable of supporting the industry. From an entrepreneurship point of view, this work intersected with Lean Startup[13], with focuses including modularity, scalability and cost efficient approaches to reduce barriers to entry in this important field.

History and Progress

The intersection between the business and marketing side of this work via the NCSU College of Agriculture Entrepreneurship course and the engineering of a portable oyster hatchery in a Senior Design course in Biological and Agricultural Engineering provided a unique way to move this project forward. Specifically, a business model was developed using Lean Startup[13] methods.

From an engineering perspective, the design provided a way of producing high quality oyster spat in a portable hatchery that could fit on the back of a trailer. This system could be scaled, but a preliminary design is shown in figure 1, with relevant water quality components such as filtration, aeration and other unit operations in a space about 1 meter wide by 1.5 meter high by 1.6 meters long. This was a critical part of the system and provided a focus on high quality water for the hatchery.

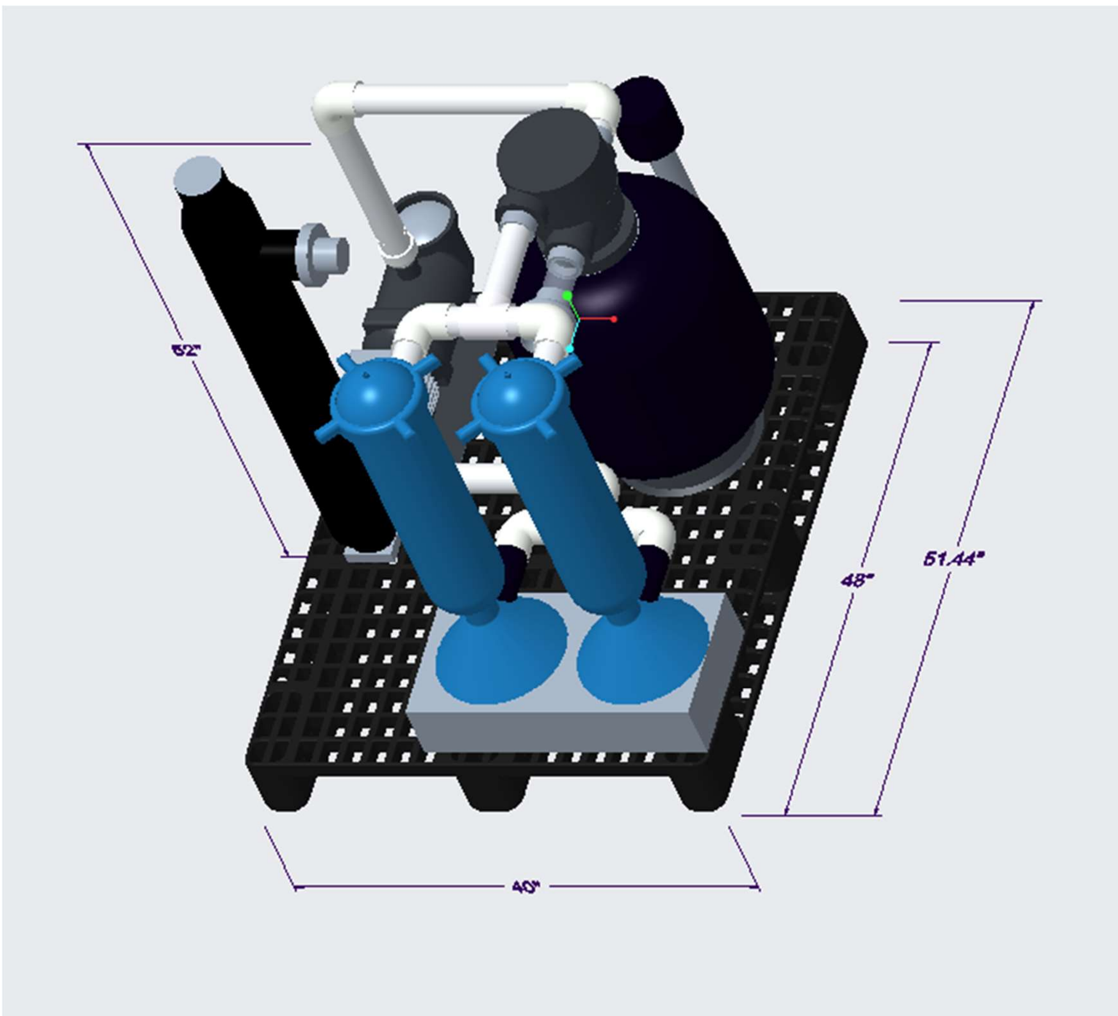

Figure 1: The components in this portable hatchery system included filtration, aeration, sterilization and relevant plumbing. The package was designed to be space efficient, lightweight, modular, scalable and portable.

While the engineering of a system to provide high quality water had to be linked with healthy mature broodstock (requiring biological expertise and input), the system could then be fed with locally grown or paste type feed, providing flexibility in terms of operation. Consideration of these physical design constraints in the context of entrepreneurship helped in enhancing the impact of the design process on education objectives. For example, since students were required to build a real physical model of the device, satisfy business, biological and practical objectives, the experience of active learning enhanced the learning process. Discussion with the team suggested that the interaction with a wider variety of "clients" helped enhance communication, while still encouraging the development and application of technical skills[14].

Entrepreneurial Output and Collaborations

There was interplay between engineering, economics and biology in this project. Specifically, the life cycle of the oyster (*Crassostrea virginica*) and the water quality needs of the species during different parts of the life cycle were driving factors[15, 16]. However, economic limitations and optimization from an engineering perspective were parts of the interplay. This unique combination of biological, economic and engineering objectives required further interaction between engineers, economists, business and biological professionals and added complexity to the overall project, what some call "innovative spaces" [17].

The focus of what is presented here was only part of the overall project, but a key component: critical water quality during the larval stage of the life cycle. In terms of the engineering aspects driving selection and ordering of components, key aspects were to keep the system mobile – therefore implying a small footprint as seen in Figure 1; scalable – since there will be different production needs in different areas; manufacturable – using primarily commercially available parts; economic – which implies limits to costs from a materials and capital cost; but also keeping operational (specifically energy and labor) costs low by making devices efficient and ergonomically friendly. The small footprint has implications from a business point of view for example. Simultaneously, the oyster life cycle itself and the value of oyster larvae impacted the economics and thus the design. Another aspect of this design was to use sequential filtration to reduce operational costs and pressure differential in the system while keeping economic costs reasonable.

Another aspect driving the overall project was the fact that permanent hatchery facilities require significant capital expenditure but are then impacted by challenging coastal events such as hurricanes or subsidence. By moving to a portable hatchery, some of the key components (but likely not some of the lower cost and larger components) could be removed when a hurricane or tropical storm is impending. This could justify the added design costs and may even help with overall efficiency by focusing design effort on areas that can reduce losses and enhance overall resilience of the system. The experience of the Senior Design students in doing this process is important to the overall educational objectives[18, 19]. Entrepreneurship and innovation between business and engineering is growing worldwide. This project focused students and advisors on enhancing this aspect of the learning process.

Previous work focused on the intersection between biology and engineering[20, 21, 22, 23,24], but this work brings the economic perspective to the biological/engineering interface. Thus, the linkage between economics and engineering, coupled with the biology of the system driving the design, has provided a unique learning experience for the students and some novel but accessible approaches to a design for this mobile scaleable oyster hatchery system. Specific learning objectives included enhanced communication, hands-on and active learning, and optimization with both engineering, economic and environmental factors considered. While this added unique challenges, it developed communication and other soft skills while still working with the engineering technical skills that help differentiate engineers from other professionals. Thus, the entrepreneurial aspects, coupled with enhanced communication needs and multidisciplinary engineering skills development, provided a unique learning environment.

Discussion and Conclusions

This project provided Biological and Agricultural Engineering capstone Senior Design students with the opportunity to interact with biological, business and manufacturing professionals. As part of the review process, both industry and academic professionals provided feedback[25], while the ongoing relationship with the business and economics personnel helped keep the students focused on real-world constraints. This emphasis on mentoring as well as sustainability reflects results from the literature that suggest that interaction with mentors and advisors can enhance student experience and learning objectives[25,26]. In this case, mentors included commercial, economic, biological and engineering experts, challenging students but expanding opportunities for creativity, which has been documented to contribute to sustainability[27]. Active learning can enhance inductive learning which complements the more traditional deductive reasoning more common in traditional engineering curricula[28]. Finally, the biology of the system itself, specifically the need to provide excellent water quality for the oysters during the hatchery and growout process, encouraged the engineers to consider the interaction between biology, economics and engineering, reflected in previous literature as an area of needed design consideration and development[29].

In summary, this project was actually more complex than initially suggested due to the ongoing interaction between these disparate factors. However, this enhanced the richness of the design experience and enhanced the quality of the overall product. Students engaged in engineering which itself required some understanding and integration between biology and physics; while also engaging entrepreneurship in the overall engineering education[30, 31]. At this point in the curriculum (e.g. Senior standing for Senior Design or Capstone Project Course), it is an opportunity to bring to bear the theory learned in previous courses, but also to extend the learning process to allow students to interact with biology, business and other personnel as they prepare to enter the workforce.

Decisions in the overall project considered economics, biology, engineering and communication. It is possible that this type of design will be used across the industry, or may be applied in certain areas where mobility adds competitive advantages. This could be a way of reducing the barriers to entry by using this type of system in a rental or franchise type system. If successful, similar portable systems might be applied in other marine aquaculture systems where the competitive advantages allow improved robustness and/or reduced operational costs. Given the increasing frequency and severity of coastal storms and ongoing impacts from storm events, finding ways to allow key high-value components of systems to be easily removed from dangerous areas; and possibly also allowing these systems to be used over longer periods of the year (possibly starting further south in early spring and moving north as temperatures change) could be key advantages allowing these type of systems to provide competitive advantages.

Regardless of commercialization details, the learning process for the students (and likely the opportunity for sponsors to hire top young engineers) has high value in and of itself. Research suggests that both business and academia, in the US and across the globe are recognizing and embracing the need to provide engineering education that allows students to learn from these multidisciplinary and entrepreneurial opportunities[32,33]. It is likely that collaborative and cross cutting technologies and techniques like this will become more common and training young engineers to communicate well across design, biological and economic fields will continue to yield value.

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