Growing Infrastructure: Entrepreneurial Thought and Action to Develop Coastal Bioengineering Technologies, From Education to Sustainable Production

Steven G. Hall[1], Matthew D. Campbell[1], Tyler Ortego[2], Robert Beine[2]
North Carolina State University, Department of Biological and Agricultural Engineering; Oratechnologies LLC

Abstract

A professor, senior design students and collaborators dreamed of growing infrastructure, instead of just building it. In the coastal southeast, focus on living infrastructure was as natural as coastal subsidence and land loss is a serious challenge. This group eventually designed and patented a series of technologies that have since spawned an entire industry in living coastal infrastructure, and has specifically added a much more developed engineering approach to the field. We explored the educational process that enabled some of those students to start companies, patent technologies, and participate in small and larger companies in the field, as well as the ongoing adventures and thoughts of those involved. We also considered the use of these techniques to provide examples, warnings and encouragement to students present and future so that they too can impact the world in a positive and restorative way, while building communities and value.

Keywords

Living infrastructure; coastal bioengineering; oysters; coastal resilience; reefs

Introduction

Coastal communities and infrastructure are challenged with rising sea levels and energetic storm systems[1]. Simultaneously, more people are living in the coastal zone than ever before[2]. Many individuals and communities are hardening infrastructure at great cost economically and environmentally. Among the challenges: protecting coastal infrastructure; minimizing or reversing loss of coastal habitat; and keeping costs reasonable on alternative solutions. A series of undergraduate senior design and graduate research students developed a number of creative alternatives over the past two decades, pursuing a series of patents; starting a number of companies; licensing technology to other companies; growing small companies and working with larger companies to grow the technology and add value. It has been documented that active learning can enhance student learning[3]. Design-build projects at undergraduate and graduate teaching can help keep action in the process. However, patenting, licensing and developing spinoff companies further develops unique skills that are challenging in the classroom but critical in moving technical ideas into the real world. In this sense, entrepreneurship in engineering curricula should enhance bringing ideas to market and developing technical and soft skills that engineers need in the job market[4,5].

History and Progress

A group of capstone design students were working on new ways to improve coastal protection. With more people at the coast; strong storms; and relative sea level rise all contributing to coastal concerns, the group had a focus. Recent work has suggested not only that there can be significant impact to the coast itself by large storms, but also that other impacts, such as health effects due to flooding can also be critical challenges[1,2]. Interestingly, some of this work also acknowledges that biology such as reefs or vegetation can have a significant protective effect[2]. The interest in the problem was natural. In addition, coming from a biological engineering approach and with a recognition of limits to resources, there was an emphasis on low-cost, environmentally friendly technologies. What emerged after much experimentation was a simple frame structure designed to encourage encrusting organisms such as oysters to grow on the frame, increasing mass and stability of the device[6,7].

Entrepreneurial Output and Collaborations

Ongoing research and development led to a number of patents and publications. Three specific technologies and their resulting output and collaborations will be discussed here. These three are 1) E nvironmentally friendly concrete (oysterkrete) [6,7], 2) i nterlocking frameworks for emplacement and growth, often in intertidal wave breaks (oysterbreaks) [8,9], and 3) a novel digital manufacturing method to produce biofriendly coastal reefs quickly and at low cost) [10]. Each of these technologies has had technical challenges, which we will discuss briefly; and entrepreneurial aspects to their development which will be a significant focus. The engineering education and pedagogical benefits come from both being challenged by multiple technical issues, such as biology and physics; but also from the inductive learning that occurs in these environments. This type of learning should enhance learning outcomes[11]. It has also been documented that this type of innovation may enhance sustainability[12].

Developing a material (later dubbed oysterkrete) that would be friendly to encrusting organisms but still strong enough to support itself during emplacement and not fail during large storm events was a significant technological challenge, while 3-D printing of biofriendly structures was a later development[13,14]. Author Beine's expertise in agricultural chemistry and awareness of agricultural byproducts that could release biofriendly compounds led to the inclusion of various biological materials including waste cotton seed; wood chips, expanded clay and other alternative materials[15,16,17]. Adding biomaterials to concrete, however, has its own challenges, so finding ways to include this material while still maintaining at least modest structural strength was important to this development.

This work required creativity and also had an entrepreneurial aspect to it in that the students were required to seek out expertise and communicate across disciplinary boundaries. This led to consideration of how these entrepreneurial aspects could be introduced to students, and how this in turn could contribute to enhancing sustainability, especially in this case in sustainable coastal development[18,19].

This need, in turn, led to consideration of physical embodiments which would allow for interlocking frameworks and emplacement in coastal waters. Preliminary work was done with small (45cm diameter) rings[20,21,22]. These were emplaced and grew to become biologically dominated. When patents emerged from this work, a small company, ORA Technologies, was formed by the authors. These first two technologies were later licensed and the technology was further developed to allow for emplacement. There are now kilometers of emplacements in the coastal regions of the Gulf of Mexico including a demonstration federally funded project that encouraged commercial production of molds; higher strength concrete; and effective transportation and emplacement techniques. One configuration is shown in figures 1 and 2.

Figure 1. Biofriendly coastal protection devices shortly after emplacement in Gulf Coast marsh area. Rings lock together, are placed parallel to shore, but allow water and nutrient flow through the porous emplacement.

Figure 2. Emplaced biofriendly devices after becoming biologically dominated. These appear and have become part of the environment, and provide sustainable, growing coastal protection.

This emplacement (Figures 1 and 2) shows a typical configuration parallel to shore, in a biofriendly context, with very preliminary biological growth (Fig 1) and after two seasons of growth (Fig. 2). This emplacement already provides protection to the coastal habitat behind, but still allows water flow and flushing to enhance health. The emplacement actually represents the entire series of problem definition, conceptualization, design and development, testing, patenting, licensing, legal hurdles to emplacement, transportation, capitalization and emplacement.

One challenge noted during this phase of development was that exclusive and lenient licensing terms encouraged some level of production but did not encourage substantial growth of the company or emplacements. Other than minimum royalties, little incentive was in place to further develop emplacement beyond minimal efforts to keep licensing company cash flow positive. This led to the recognition that improved mentoring could encourage more successful entrepreneurial technology transfer[23]. Further consideration of effective techniques for both the pedagogy but also the practice is needed to enhance technology transfer and result in sustainable and effective outcomes[24]. Some studies suggest entrepreneurial activities can enhance GPA and retention[25], the challenges of technology transfer in the real world may still require additional mentoring for success[23].

Although this has ended up being a part of the overall learning process, the lenient terms were given by the inventors to the licensee in part due to a mix of naivety and idealism of the inventors. Although this is not an impossible situation to operate from, the result was that a wider adoption of the technology has not been realized. On the other hand, emplacing the right incentives would have enabled a more rapid development and commercialization of the technology.

Thus, the inventors embarked on development of new technologies including the recent development of a digital manufacturing method[14] that avoids the need for molds and allows for a wider array of geometries. Furthermore, this technique allows printing that is quite fast (minutes to hours for meter sized prints); and relatively inexpensive where sufficient material is available (for example, in many coastal areas).

A new company has been formed to further develop this technology and the inventors are working with larger companies but have not yet signed any exclusive licenses. This allows further development of the technology without the exclusivity or limits in previous venues. Ultimately, bringing these technologies to locations where they are needed, and at a cost that is acceptable in both economic and environmental terms is the goal. Small companies and an entrepreneurial attitude could be one way to move forward in this effort, and may allow significant high value emplacements in the US and other developed areas; but may also allow low-cost emplacements in island and coastal nations with fewer resources, thus protecting coastal communities and enhancing local fisheries, while hopefully providing local employment in the emplacement, management and monitoring of the resulting reefs.

It should also be noted that other technologies and further research both on artificial reefs[26,27,28]; and on parallel technologies, such as techniques to monitor the reefs or water near reefs[29,30].

Many of these involved further students and collaborators and have resulted in new research publications as well as ongoing technology development. Thus, healthy entrepreneurship in this case not only took technology and concepts from research to development to production; but also "keeps in touch" to inform ongoing and future research that can further enhance and possibly eventually lead to further patents, development and positive impacts in the world. Former students, including authors of this publication, have become mentors to recent students, thus enhancing engineering education and providing current real world insights from entrepreneurial enterprises. Ultimately, the professors and professionals have experienced ongoing learning and hope this will enhance future engineering pedagogy.

Conclusion

In conclusion, while university work is often thought of as "training" at the undergraduate level, or as focused on "research" with heavy emphasis on journal publications at the graduate level, adding an entrepreneurial aspect to this work has allowed well trained and creative individuals to both do some good learning and discovery[5,23]; but also develop some of those ideas into patents, which led to licensing; and spun up some small businesses; and opened doors for interactions with larger businesses. We learned to remain creative; to be open to new ideas; but also to consider how to reduce ideas to practice, especially concepts related to growing infrastructure and coastal bioengineering. In more recent classes; and with more recent students, this has become more explicit: young entrepreneurs come and give guest lectures; student projects are linked to local companies as appropriate; graduate students are strongly encouraged to produce not only peer reviewed journal articles but also patentable technologies; extension publications that address very practical aspects of our work; and to consider entrepreneurial aspects of our work. In so doing, significant value was realized from actual projects that were built and emplaced, with positive impacts in both economic and environmental arenas.

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Author

Steven G. Hall, PhD, PE is co editor in chief of the Elsevier Journal Aquacultural Engineering; Associate Professor and Director of the Marine Aquaculture Research Center in the Department of Biological and Agricultural Engineering at North Carolina State University. He received a BS (Mechanical Engineering) from the University of Buffalo; MS from UC Davis; PhD from Cornell University, was the first Sustainable Agriculture Postdoctoral Fellow at McGill University; and served on faculty at LSU and the Au Sable Institute. He has teaching, research and extension appointments, speaks regularly to K-12, university, graduate and professional audiences; while focusing on productive and sustainable aquatic solutions.