CASE STUDY

Integrating Entrepreneurship and Art to Improve Creative Problem Solving in Fisheries Education

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We adapted instructional activities from entrepreneurship and art training to improve student skills in creative problem solving in fisheries and natural resource fields. The teaching module included: (1) individual exercises that apply specific thinking strategies to improve originality, flexibility, and fluency for creative thinking; (2) group exercises using an entrepreneurial business framework for collaborative, creative problem solving that focuses on effective brainstorming and decision making; and (3) art inquiry experiences centered on creating emojis to help students explore and communicate their experiences in the field. These techniques were introduced and practiced during an undergraduate sustainable fisheries field course to creatively address topics ranging from reducing bycatch in fishing gear to sustainable fisheries management, and repeated in a graduate-level short course for students in natural resources. Evaluation of student learning showed significant improvement in pre- and post-originality scores, class performance, and positive student and faculty feedback.

INTRODUCTION

A clarion call by the National Academies of Sciences, Engineering, and Medicine emphasizes that higher education in the 21st century must integrate across disciplines, including connecting the arts and sciences, to prepare the next generation of professionals to address complex challenges (NASEM 2018). Issues ranging from sustainably managing fisheries to addressing climate change require new ideas, creativity, and holistic solutions. As Albert Einstein (n.d.) noted, "We cannot solve the problems that we have created with the same thinking that created them." Although the demand for entrepreneurial skills has been recognized throughout the business world (Zucchella et al. 2018), it is increasingly needed in natural resource fields where both creative solutions and problem-solving skills are required for good science management and policy. Moreover, learning outcomes associated with interdisciplinary education, such as critical and creative thinking, and communication and collaboration skills, are increasingly desired by employers (NASEM 2018), including those in fisheries agencies and industry (McMullin et al. 2016). Yet while business schools and engineering programs have exploded with curricula to encourage innovative entrepreneurship—"a dynamic process of vision, change, and creation" (Kuratko 2005)—fisheries programs have lagged behind despite calls for new curricula (e.g., Colvin and Peterson 2016; Terre 2016).

To address this challenge, we developed a learning module that enhances innovative thinking in aspiring scientists at a university field station and marine laboratory. We introduced fisheries and other natural resource students to a suite of activities intended to develop their creative dispositions and problem-solving skills. Field courses offer students direct experiences in natural areas to help them develop an understanding of the complexity and interaction of physical, natural, and social systems (NRC 2014). Field courses traditionally teach natural science and ecological processes, but may fall short of their potential because interdisciplinary perspectives are often not engaged to enhance other ways of understanding the world beyond technical scientific frameworks (Turner and Freedman 2004). This limits the development of creativity among young scientists.

Creative thinking—"The experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking" (AACU 2010)—is needed to innovatively address environmental resource management, especially fisheries problems on a local and global scale. Researchers have found that teaching creative thinking requires using explicit strategies that promote cognitive flexibility. "Students need to be repeatedly reminded and shown how to be creative, to integrate materials across subject areas, to question their own assumptions, and to imagine other viewpoints and possibilities" (DeHaan 2009). Fisheries scientists often face complex problems that have many paths and multiple possible solutions, yet in the classroom, there is little teaching of higher-order thinking skills, of which creativity is the most complex (DeHaan 2009).

We tested a variety of field-based activities adding art inquiry and entrepreneurship training to conventional scientific investigations. The resulting module adapted activities from business and the arts that can be readily added to existing fisheries courses. Our goal was to teach students that a "good thinker" must develop a repertoire of creative (also called divergent or associative) thinking and collaborative problem-solving skills, to complement the critical thinking skills often emphasized in science disciplines.

We tested the module with students at a field course in sustainable fisheries at the Shoals Marine Laboratory (operated by Cornell University and the University of New Hampshire), located on Appledore Island, Maine, and repeated the exercises in a short-course format at the Universidad Austral de Chile for graduate students in ecology and natural resources. We developed an integrated set of three activities that helped to build learner capacity for independent creative thinking and collaborative group problem solving. The first activity helped students identify cognitive barriers to creativity and learn simple thinking strategies to overcome them. The second activity introduced a systematic method for collaborative problem solving, used in business schools to teach brainstorming and collaborative decision making (Parnes 1992). The third exercise incorporated an art-making activity. Art offers students an experience that can help them understand the creative process, examine the world in different ways, stimulate new dialogues, and facilitate an emotional connection to fisheries or other fields (Jacobson et al. 2007); thus enhancing creative problem-solving approaches. Once students become familiar with the concepts and steps for thinking creatively as individuals and in groups, the techniques were reiterated during the course to enhance their traditional scientific investigations. The goal of the module was to enhance students' ability to produce transformative insights (Repko and Szostak 2016) and ensure students are able to adopt a creative disposition to solving fisheries and natural resource management problems in the future.

METHODS

Participants

The module was integrated into the Sustainable Fisheries course (Cornell:BioSM2800/UNH:MEFB 702), June 12–26, 2017. All undergraduate students (n = 6) participated. The module was repeated in a short course format for graduate students and recent graduates in natural resources and ecology at the Universidad Austral de Chile, Institute of Ecology and Biodiversity (n = 28), in Valdivia, Chile.

Activity 1: Creative Thinking Skills

Fostering Individual Creativity—Paper Clip and Incomplete Figure Challenge (1 h)

The first activity provided students with basic exercises to enhance creative thinking. Developed for creativity testing in the 1960s by psychologist Ellis Paul Torrance, participants transform a simple image into as many items as possible (Lissitz and Willhoft 1985). Through practice, becoming more dexterous in generating fluency, flexibility, and originality of ideas can help students learn how to restructure problems and produce innovative solutions (DeHaan 2011). We discuss barriers to creativity and emphasize how students can learn to use specific thinking strategies to individually and collectively address problems. Students were asked to use their imaginations and list as many uses as possible for a paperclip in 2 minutes. Students shared their responses with a partner to identify and score them quantitatively across four scales: fluency (number of different uses of the paperclip), flexibility (the number of different categories covered), originality (how uncommon the uses are in relation to the responses of their classmates, only unique responses are counted), and elaboration (the amount of detail in each response, only measured descriptively in our analysis). Practicing these simple exercises with different subjects helps students learn skills for innovation (DeHaan 2011).

Once students explored the concepts of fluency, flexibility, originality, and elaboration with the paper clip challenge, they practiced with an additional exercise that challenged them to create as many images as possible from an incomplete figure, the letter V, in a two-minute period. Students then assessed their own figures across the four scales and discussed the originality scale by comparing answers with the entire class. Students completed the paperclip activity again at the end of the module as part of the assessment of the development of their creativity strategies.

Activity 2. Entrepreneurship Skills

Collaborative Creative Problem Solving—Water Filter Challenge (1 h)

The second exercise introduced a systematic method for project collaboration, the Osborn–Parnes model of Creative Problem Solving (CPS), which emphasizes innovative thinking in groups (Parnes 1992). The framework uses a creative, divergent thinking phase in which participants generate lots of ideas (problem definitions, evaluation criteria, implementation strategies), and then a convergent or critical thinking phase in which criteria are selected for making judgments and the most promising ideas are further explored.

We introduce students to the six steps of the CPS model using a workbook format that is available online (Mitchell and Kowalik 1999). The steps include:

(1) Mess finding (goal identification)
(2) Fact finding
(3) Problem finding
(4) Idea finding
(5) Solution finding
(6) Acceptance finding (implementation).

The students worked in groups of three to six individuals, depending on the size of the class. They were provided with the workbook outlining the CPS Model and a set of materials with a specific problem to solve. We gave them the challenge of designing a water filter to "clean" a cup of very dirty water. Materials for each group included: two styrofoam cups, two clear plastic cups, one-half cup sand, one-half cup gravel, one sharp pencil, and two paper towels.

Because we defined a specific problem and materials, we asked the students to focus on Step 4 to identify at least 30 ideas for building the water filter, using the workbook guidance on brainstorming techniques. This requires that students share many wild ideas and follow specified techniques to enhance originality. Students recognize that they must become more fluent in ideation by combining and spinning off from the ideas of others to reach the 30-idea limit. The CPS Model encourages the students to follow the acronym SCAMPER (substitute, combine, adapt, magnify, put to other uses, eliminate, reverse) to stimulate ideas (Mitchell and Kowalik 1999). The students then complete Step 5, solution finding, to identify criteria to evaluate the ideas and select a workable solution. A contest to filter dirty water ends the exercise with the group producing the cleanest cup of water winning first place.

Activity 3: Art Inquiry Process Skills

Emoji Challenge (1.5 h)

Many field stations host visiting artists (NRC 2014) and many research institutions have been promoting arts integration in higher education (Mackh 2015), yet art faculty may not think to interact with science students in meaningful ways. In our module, the artist created an exercise specifically for fisheries undergraduate students to think about the world using different perspectives. Students are encouraged to create a new idea, by looking for hidden analogies and simplifying, adding, or subtracting things to develop and communicate original ideas.

The objective of the art activity was to help students practice their ability to use their imagination to transcend traditional ideas, rules, patterns, and relationships. The visiting artist at Shoals Marine Laboratory (Janis Goodman) decided that students in the sustainable fisheries course would benefit from an art experience that could help them digest and summarize their course. Students often believe that one is either born creative or not, and do not realize that creativity is a skill that can be enhanced and practiced. The art inquiry further helped students realize they could be imaginative regardless of artistic skill. The art activity focused on ideograms typically used in contemporary social media. They were asked to design a series of simple emojis that would be a shorthand for all their learning and experiences in the course. Students were supplied with paper, colored pencils, and watercolor paints. They designed emojis that were both humorous and poignant. The class discussed the universal notation of emojis and explored personal issues as well as scientific ones. The students were encouraged to consider their boat trips and equipment used on the trawlers, the types of fish they had studied, the movement of water, the varying temperatures on the island, their term projects, and any other experience or iconic image that resonated with their field stay and course. The natural resource graduate students were asked to contemplate and depict their research and work experiences. Conversation and often laughter accompanied the recall and sharing of their experiences.

Reinforcement of Key Concepts Throughout Course

Components of the creative thinking module were integrated with the field component of the fisheries course during our time on board a commercial fishing vessel engaged in trawling for groundfish. Under the supervision of the fisherman and instructors, students compared catches from two different nets, each of which was designed to target different species based on mesh type relative to fish body shape. Using the SCAMPER technique, students shared innovative ideas to redesign trawler nets to reduce bycatch. Fishing gear modifications to reduce bycatch are an important component of fisheries management, and both the science (design, testing) and implementation (transferring lessons learned to industry) of such measures require creative problem solving and elements of visual, verbal, and written communication. Faculty also emphasized the value of creative thinking as students practiced the process when trying to envision alternative scenarios for improved fisheries management through a mock stakeholder negotiation. The acronym SCAMPER became an easy and fun shorthand to remind students to practice thinking innovatively. The emojis or use of symbols also was reinforced in a subsequent activity in which they had to map an estuary. Since natural science often requires mapping and graphing, the ideogram is a perfect instrument for individual notation that conveys larger content. The emojis became a shorthand for remembering, digesting, and communicating huge amounts of information in a relatively short amount of time. In the graduate student module, participants worked in groups and identified their own natural resource problems to practice applying the six-step CPS model outlined in the workbook. Problems ranged from involving indigenous people in resource management to sustainable agricultural practices.

Assessment

To statistically analyze general trends in improvement in student creativity before and after the module, we used a non-parametric Wilcoxon Signed-Rank test, which is a paired difference test, as well as the Common Language Effect Size Statistic (hereafter: Effect Size), which denotes a large effect size when greater than 0.8 (McGraw and Wong 1992) to accommodate the small sample sizes and non-normal distribution. We compared before and after scores in fluency, flexibility, and originality using the paperclip challenge and the scoring metric of DeHaan (2009, 2011). As described in Activity 1, the originality scale measures how uncommon the responses are in relation to the rest of the class; only unique responses are counted, thus the exercise is useful as a pretest–posttest metric on creativity because it only measures the number of unique responses per student. Performance in class and student evaluations also were used to assess the module.

RESULTS

The students in the sustainable fisheries class all improved their scores on average in fluency by 69%, pretest x = 7.50 (SD = 2.90), posttest x = 12.67 (SD = 4.10); Wilcoxon Signed-Ranks $P = 0.03$, Effect Size = 0.83; flexibility by 51%, pretest x = 7.17 (SD = 2.63), posttest x = 10.83 (SD = 2.79); Wilcoxon Signed-Ranks $p = 0.02$, Effect Size = 0.83; and originality by 227%, pretest x = 1.17 (SD = 1.17), posttest x = 3.83 (SD = 1.72); Wilcoxon Signed-Ranks $P = 0.00$, Effect Size = 1. Participants in the module offered as a graduate student short course also showed improved scores: fluency increased on average by 35%, pretest x = 6.71 (SD = 2.79), posttest x = 9.07 (SD = 4.15); Wilcoxon Signed-Ranks $P = 0.02$, Effect Size = 0.82; flexibility by 32%, pretest x = 6.28 (SD = 2.62), posttest x = 8.32 (SD = 3.34); Wilcoxon Signed-Ranks $P = 0.02$, Effect Size = 0.92; and originality by 156%, pretest x = 0.82 (SD = 0.86), posttest x = 2.11 (SD = 1.73); Wilcoxon Signed-Ranks $P = 0.0004$, Effect Size = 0.80. In both modules, the types of items enumerated expanded from fairly literal (hair clip, bookmark) to more elaborate (engraver, fondue dipper) and imaginary (mini-trombone, fidget toy).

We included elements from the creative problem solving and art inquiry activities in our periodic quizzes in the sustainable fisheries class to also underscore the importance of this course content. The questions asked students to describe the use of creative and critical thinking in situations, applying the CPS Model to ideas for reducing marine mammal bycatch, and provide visual images of fish traps or ocean currents. The students were able to respond to the questions without difficulty.

Student evaluations of the module also demonstrated that they perceived they had mastered a new skill set for thinking fluently, flexibly, and originally, as well as understood the importance of thinking creatively for fisheries and natural resource management.

Fisheries students reported:

> "This material made it easier (step by step) to think and come to a solution outside the box."

> "Helped me address a problem differently, seeing my group and others think differently, new and helpful."

> "I plan to use the skills I've learned for both my academic career (balancing homework) and professional future (working with others)."

> "I learned not to always feel bound to think like a scientist…art belongs in science and really helps the learning process."

The graduate natural resources students reported:

> "The emoji activity was so interesting. I saw how my work and study have a face and place in my emotional thinking."

> "[The module] made me realize how few scientists use creative thinking and how this could improve research and science communication."

> "I think it is very important to try to apply this way of problem solving in different areas and with different people, to improve our abilities and solutions."

DISCUSSION

The challenging nature of fisheries science and management made a creative thinking module an ideal supplement to a sustainable fisheries course. Creative thinking and collaborative problem solving are necessary tools for those attempting to navigate the contentious and complex issues surrounding natural resource management, especially in the realm of fisheries. Conventional disciplinary segregation limits the breadth of students' exposure to other disciplines and hence other ways of understanding their world (NASEM 2018). There are many options for improving teaching in fisheries science, but our focus was unique in that it specifically aimed at improving creativity and innovative problem solving.

Entrepreneurial processes and strategies provide fundamental approaches for rethinking fisheries management. The Osborn–Parnes model of Creative Problem Solving is based upon generating many different ideas through brainstorming and deferred judgment—thus expanding habitual ways of thinking. The activities we conducted were easy to introduce into an undergraduate fisheries course as well as a short course for graduate students in natural resources. The basic cognitive exercises for practicing a creative thinking disposition are described in DeHaan (2011). Any simple item such as a paperclip, plastic bottle, or a printed triangle, can serve as the subject for practicing fluency, flexibility, and originality. The instructions for practicing collaborative problem solving are available online (Mitchell and Kowalik 1999). The workbook format allows students to document and track their progress through the framework. Faculty can give students a circumscribed problem like our water filter challenge before encouraging them to choose their own problem to address collaboratively in small groups. The faculty found these frameworks particularly relevant for a course on sustainable marine fisheries given the ongoing challenges and need for creative solutions in this sector.

The recent focus on integrating STEM (science, technology, engineering, and math) disciplines with the addition of the arts (STEAM) is intended to teach students creative means of expression, an understanding of different perspectives, and a greater "awareness of knowledge and emotions throughout the human experience" (NASEM 2018). The concept of The Artist is one of four roles of a creative process emphasized by Von Oech (1986), a leader in entrepreneurship training who uses the artist as a lens to make, modify, or transform ideas or things. The emoji art activity provoked the students to think differently about how to explore and communicate their experiences. We chose this activity because it required no conventional artistic skill. We have found other non-representational art activities, such as making a found-art collage to explore the process of climate change, eliminated a widespread worry ("I'm not an artist"), or the urge to fear or judge the products (Jacobson et al. 2015, 2016). We have also used basic art exercises to help students examine natural phenomenon in a novel way, such as exploring an oyster reef with an artist and producing crumpled paper sculptures to try to represent the enormous interstitial space between oysters in an oyster bar. The graduate student group explored the contours of leaves while drawing them with their eyes closed. Science students engaging in simple art exercises such as these report that the experiences help them look at the natural environment in a different way and identify emotional and cognitive barriers to creativity.

It is difficult to evaluate interdisciplinary learning and there is "scant empirical literature" (NASEM 2018). Multiple forms of evaluation can be used to assess interdisciplinary education, including qualitative or quantitative surveys, narration, portfolios, and expert opinion. We used student evaluations and the paperclip challenge, a version of a Torrance Test of Creativity (Lissitz and Willhoft 1985), to evaluate the impacts of the module on creativity in our students. This was built into the instructional experience. In the future a controlled, randomized, longitudinal study would allow us to determine the specific role this module can play in the development of higher order cognitive skills and creative problem solving across the disciplinary spectrum. Although longer duration programs integrating entrepreneurship and arts with science are desirable and could have deeper curricular impacts, these short activities provided students with an initial glimpse of the benefits of transcending traditional disciplinary boundaries to think more creatively and also become aware of available concrete methods for effectively collaborating and problem solving in groups.

The short duration of a learning experience can limit efficacy (Jacobson et al. 2015). Yet, the brevity of our module had the advantage of removing some traditional barriers for faculty to engage in interdisciplinary approaches, such as time constraints, insufficient resources, and differences in departmental cultures and evaluation (Jacobson 1995; Mackh 2015). The specificity and simplicity of the activities addressed the concern that both faculty and students may lack art or business expertise. A modular approach is also useful for demonstrating the expanded role field stations can play in helping diverse groups of students and faculty acquire new ways of approaching emerging problems and situations. It is increasingly obvious that we must bridge the divide that separates the cultures of art, business and science in order to creatively solve the many complex and pressing problems in natural resource management and transform how we educate tomorrow's leaders.

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