

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

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Abstract

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 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, p. 578) – fisheries programs have lagged behind despite calls for new curricula (e.g., Colvin and Peterson 2016, Lederman et al. 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 & Freeman 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 n.d., p.1) – 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, p172). 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),

99 located on Appledore Island, Maine, and repeated the exercises in a short-course format at the
100 Universidad Austral de Chile for graduate students in ecology and natural resources. We
101 developed an integrated set of three activities that helped to build learner capacity for
102 independent creative thinking and collaborative group problem solving. The first activity helped
103 students identify cognitive barriers to creativity and learn simple thinking strategies to overcome
104 them. The second activity introduced a systematic method for collaborative problem-solving,
105 used in business schools to teach brain-storming and collaborative decision-making (Parnes
106 1992). The third exercise incorporated an art-making activity. Art offers students an experience
107 that can help them understand the creative process, examine the world in different ways,
108 stimulate new dialogues, and facilitate an emotional connection to fisheries or other fields
109 (Jacobson et al. 2007, Levinthal 1988); thus enhancing creative problem-solving approaches.
110 Once students become familiar with the concepts and steps for thinking creatively as individuals
111 and in groups, the techniques were reiterated during the course to enhance their traditional
112 scientific investigations. The goal of the module was to enhance students' ability to produce
113 transformative insights (Repko 2012) and ensure students are able to adopt a creative disposition
114 to solving fisheries and natural resource management problems in the future.

115 116 117 **METHODS**

118 119 **Participants**

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

126 127 **Activity 1: Creative thinking skills**

128 *Fostering individual creativity – Paper clip and incomplete figure challenge* (1 hour)

129
130 The first activity provided students with basic exercises to enhance creative thinking.
131 Developed for creativity testing in the 1960s by psychologist Ellis Paul Torrance, participants
132 transform a simple image into as many items as possible (Lissitz and Willhoft 1985). Through
133 practice, becoming more dexterous in generating fluency, flexibility, and originality of ideas can
134 help students learn how to restructure problems and produce innovative solutions (DeHaan
135 2011). We discuss barriers to creativity and emphasize how students can learn to use specific
136 thinking strategies to individually and collectively address problems. Students were asked to use
137 their imaginations and list as many uses as possible for a paperclip in 2 minutes. Students shared
138 their responses with a partner to identify and score them quantitatively across four scales:
139 fluency (number of different uses of the paperclip), flexibility (the number of different categories
140 covered), originality (how uncommon the uses are in relation to the responses of their
141 classmates, only unique responses are counted), and elaboration (the amount of detail in each
142 response, only measured descriptively in our analysis). Practicing these simple exercises with
143 different subjects helps students learn skills for innovation (DeHaan 2011).

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

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152 **Activity 2. Entrepreneurship skills**

153 ***Collaborative Creative Problem Solving - Water filter Challenge*** (1 hour)

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

161 We introduce students to the six steps of the CPS model using a workbook format that is
162 available online (Mitchell and Kowalik 1999). The steps include: (1) Mess Finding (goal
163 identification), (2) Fact Finding (3) Problem Finding (4) Idea Finding (5) Solution Finding, and
164 (6) Acceptance Finding (implementation). The students worked in groups of 3-6 individuals,
165 depending on the size of the class. They were provided with the workbook outlining the CPS
166 Model and a set of materials with a specific problem to solve. We gave them the challenge of
167 designing a water filter to ‘clean’ a cup of very dirty water. Materials for each group included: 2
168 styrofoam cups, 2 clear plastic cups, .5 cup sand, .5 cup gravel, 1 sharp pencil, and 2 paper
169 towels.

170 Because we defined a specific problem and materials, we asked the students to focus on
171 Step 4 to identify at least 30 ideas for building the water filter, using the workbook guidance on
172 brainstorming techniques. This requires that students share many wild ideas and follow specified
173 techniques to enhance originality. Students recognize that they must become more fluent in
174 ideation by combining and spinning off from the ideas of others to reach the 30-idea limit. The
175 CPS Model encourages the students to follow the acronym SCAMPER to stimulate ideas
176 (Substitute, Combine, Adapt, Magnify, Put to other uses, Eliminate, Reverse) (Mitchell and
177 Kowalik 1999). The students then complete Step 5, Solution-Finding, to identify criteria to
178 evaluate the ideas and select a workable solution. A contest to filter dirty water ends the exercise
179 with the group producing the cleanest cup of water winning first place.

180

181 **Activity 3: Art Inquiry Process Skills**

182 ***Emoji Challenge*** (1.5 hours)

183

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

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

207

208 **Reinforcement of Key Concepts throughout Course**

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210 Components of the creative thinking module were integrated with the field component of
211 the fisheries course during our time on board a commercial fishing vessel engaged in trawling for
212 groundfish. Under the supervision of the fisherman and instructors, students compared catches
213 from two different nets, each of which was designed to target different species based on mesh
214 type relative to fish body shape. Using the SCAMPER technique students shared innovative
215 ideas to redesign trawler nets to reduce bycatch. Fishing gear modifications to reduce bycatch are
216 an important component of fisheries management, and both the science (design, testing) and
217 implementation (transferring lessons learned to industry) of such measures require creative
218 problem solving and elements of visual, verbal and written communication. Faculty also
219 emphasized the value of creative thinking as students practiced the process when trying to
220 envision alternative scenarios for improved fisheries management through a mock stakeholder
221 negotiation. The acronym SCAMPER became an easy and fun shorthand to remind students to
222 practice thinking innovatively. The emojis or use of symbols also was reinforced in a subsequent
223 activity in which they had to map an estuary. Since natural science often requires mapping and
224 graphing, the ideogram is a perfect instrument for individual notation that conveys larger
225 content. The emojis became a shorthand for remembering, digesting, and communicating huge
226 amounts of information in a relatively short amount of time. In the graduate student module,
227 participants worked in groups and identified their own natural resource problems to practice
228 applying the 6-step CPS model outlined in the workbook. Problems ranged from involving
229 indigenous people in resource management to sustainable agricultural practices.

230

231 **Assessment**

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233 To statistically analyze general trends in improvement in student creativity before and
234 after the module, we used a non-parametric Wilcoxon Signed-rank test, which is a paired
235 difference test, as well as the Common Language Effect Size Statistic (hereafter: Effect Size),

236 which denotes a large effect size when greater than 0.8 (McGraw and Wong 1992) to
237 accommodate the small sample sizes and non-normal distribution. We compared before and after
238 scores in fluency, flexibility and originality using the paperclip challenge and the scoring metric
239 of DeHaan (2009, 2011). As described in Activity 1, the originality scale measures how
240 uncommon the responses are in relation to the rest of the class; only unique responses are
241 counted, thus the exercise is useful as a pretest-posttest metric on creativity because it only
242 measures the number of unique responses per student. Performance in class and student
243 evaluations also were used to assess the module.

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RESULTS

248 The students in the Sustainable Fisheries class all improved their scores on average in
249 fluency by 69%, **pretest $x=7.5$ (SD=2.90), posttest $x=12.67$ (SD=4.1)**; Wilcoxon Signed-Ranks
250 $p=0.03$, Effect Size=0.83); flexibility by 51%, **pretest $x=7.17$ (SD=2.63), posttest $x=10.83$**
251 **(SD=2.79)**; Wilcoxon Signed-Ranks $p=0.02$, Effect Size=0.83); and originality by 227% (pretest
252 $x=1.17$ (SD=1.17), posttest $x=3.83$ (SD=1.72); Wilcoxon Signed-Ranks $p=0.00$, Effect Size=1).
253 Participants in the module offered as a graduate student short course also showed improved
254 scores: Fluency increased on average by 35% (pretest $x=6.71$ (SD=2.79), posttest $x=9.07$
255 (SD=4.15) (Wilcoxon Signed-Ranks $p=0.02$, Effect Size=.82); flexibility by 32% (pretest $x=6.28$
256 (SD=2.62), posttest $x=8.32$ (SD=3.34) (Wilcoxon Signed-Ranks $p=0.02$, Effect Size=0.92); and
257 originality by 156% (pretest $x=0.82$ (SD=0.86), posttest $x=2.11$ (SD=1.73) (Wilcoxon Signed-
258 Ranks $p=0.0004$, Effect Size=.80). In both modules, the types of items enumerated expanded
259 from fairly literal (hair clip, bookmark) to more elaborate (engraver, fondue dipper) and
260 imaginary (mini-trombone, fidget toy).

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

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

270 Fisheries students reported: "This material made it easier (step by step) to think and
271 come to a solution outside the box;" "Helped me address a problem differently, seeing my group
272 and others think differently, new and helpful;" "I plan to use the skills I've learned for both my
273 academic career (balancing homework) and professional future (working with others);" "I
274 learned not to always feel bound to think like a scientist...art belongs in science and really helps
275 the learning process."

276 The graduate natural resources students reported: "The emoji activity was so interesting. I saw
277 how my work and study have a face and place in my emotional thinking;" [The module] "made me
278 realize how few scientists use creative thinking and how this could improve research and science
279 communication;" "I think it is very important to try to apply this way of problem solving in
280 different areas and with different people, to improve our abilities and solutions."

281

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DISCUSSION

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

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

307 The recent focus on integrating STEM (Science, Technology, Engineering and Math)
308 disciplines with the addition of the arts (STEAM) is intended to teach students creative means of
309 expression, an understanding of different perspectives, and a greater "awareness of knowledge
310 and emotions throughout the human experience" (NASEM 2018 p. 60). The concept of The
311 Artist is one of four roles of a creative process emphasized by Roger von Oech (1986), a leader
312 in entrepreneurship training who uses the artist as a lens to make, modify or transform ideas or
313 things. The emoji art activity provoked the students to think differently about how to explore and
314 communicate their experiences. We chose this activity because it required no conventional
315 artistic skill. We have found other non-representational art activities, such as making a found-art
316 collage to explore the process of climate change, eliminated a widespread worry ("I'm not an
317 artist") or the urge to fear or judge the products (Jacobson et al. 2012). We have also used basic
318 art exercises to help students examine natural phenomenon in a novel way, such as exploring an
319 oyster reef with an artist and producing crumpled paper sculptures to try to represent the
320 enormous interstitial space between oysters in an oyster bar. The graduate student group
321 explored the contours of leaves while drawing them with their eyes closed. Science students
322 engaging in simple art exercises such as these report that the experiences help them look at the
323 natural environment in a different way and identify emotional and cognitive barriers to creativity.

324 It is difficult to evaluate interdisciplinary learning and there is "scant empirical literature"
325 (NASEM 2018 p. 88). Multiple forms of evaluation can be used to assess interdisciplinary
326 education, including qualitative or quantitative surveys, narration, portfolios, and expert opinion.
327 We used student evaluations and the paperclip challenge, a version of a Torrance Test of
328 Creativity (Lissitz and Willhoft 1985), to evaluate the impacts of the module on creativity in our

329 students. This was built into the instructional experience. In the future a controlled, randomized,
330 longitudinal study would allow us to determine the specific role this module can play in the
331 development of higher order cognitive skills and creative problem solving across the disciplinary
332 spectrum. Although longer-duration programs integrating entrepreneurship and arts with science
333 are desirable and could have deeper curricular impacts, these short activities provided students
334 with an initial glimpse of the benefits of transcending traditional disciplinary boundaries to think
335 more creatively and also become aware of available concrete methods for effectively
336 collaborating and problem solving in groups.

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

348
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