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Teaching Systems Thinking Concepts with Hypothetical Case Scenarios: An Exploration in Agricultural Education

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Abstract

Educators within agricultural and natural resource disciplines are tasked with educating students to critically engage with and problem-solve complex issues. As society's relationship with science and technology changes, coupled with an information-dense environment, strategies for sustainably addressing complex issues are needed. One potential approach for strategically addressing complex problems is systems thinking, which emphasizes the interdependence of the components of systems from ecological, social, and economic perspectives, among others. A mixed-methods study was used to explore the applicability of hypothetical case scenarios (HCS) as a teaching method to introduce and engage students in using systems thinking related to the seafood industry. Findings suggested HCS engaged students to think critically about socio-scientific issues. Participants demonstrated systems thinking capacity when discussing their decision-making processes in the hypothetical cases. The current study demonstrated the pedagogical potential of using HCS to enhance systems thinking capacities for students in the ANR disciplines. Implications for education and recommendations for future research are discussed.

Keywords: agricultural and natural resource education; choose-your-own-adventure learning; hypothetical case scenarios; systems thinking

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Introduction

Scholarship at the nexus of agricultural and natural resources (ANR), both in the social and natural science disciplines, aims to address many of the complex, wicked problems facing the world (Pauley et al., 2019). Previous scholars have noted the potential to find solutions to wicked problems at times may seem to be an insurmountable challenge, especially with the public being exposed to vast amounts of information daily - information which can often be contradictory and factually incorrect (Ruth et al., 2018). To address complex challenges within ANR industries, researchers, practitioners, and policymakers will "require multiple perspectives and systems thinking to develop and implement sustainable solutions" (Andenoro et al., 2016, p. 58) as public perception increasingly drives markets and industry across the globe.

The relationship between science, technology, and society has become increasingly fluid in the 21st century, with society setting much of the agenda for science and technology - a stark contrast to previous decades (Fensham, 2014). With this new relationship dynamic, it is imperative for educators within ANR disciplines to foster critical thinking skills and reframe science controversies as socio-scientific issues to account for the role of society in the decision-making and agenda-setting processes (Fensham, 2014). Socio-scientific issues are defined as complex and/or controversial issues related to science and technology (Chen & Xiao, 2021). Socio-scientific issues, purposefully integrated into students' formal science curriculum, may help connect STEM education to sustainable development (Onwu & Kyle, 2011).

One such issue within ANR is the impact of human activities on marine ecosystems (Hamilton & Safford, 2015). The human dimension of environmental issues within marine coastal ecosystems is significant (Hamilton & Safford, 2015; Rees et al., 2013). Overfishing and the contamination of marine ecosystems present a significant challenge to global food security (McLeod & Leslie, 2012). Empirically observed shifts in climate patterns, more frequent and intense weather events, ongoing changes to agricultural systems, and coastal flooding all play a role in both marine ecosystems as well as the seafood industry (Hamilton & Safford, 2015; Intergovernmental Panel on Climate Change, 2007; McLeod & Leslie, 2012). Large-scale, global changes can impact local marine ecosystems, including disruptions from algae blooms and coastal development projects that increase regional vulnerability to flooding (Bauer et al., 2010). Additionally, these changes have aesthetic, recreational, and economic consequences that impact the lives of populations living near coastal ecosystems (Hamilton & Safford, 2015).

Aquaculture and the seafood industry have the potential to help sustainably feed a growing global population and to increase jobs, including opportunities within rural areas (Mazur & Curtis, 2006). However, there are social and ecological challenges facing the seafood industry that may inhibit sustainable food production and distribution, including lack of trust, perceived risk, and tensions between local, regional, and global stakeholders with competing interests (Mazur & Curtis, 2006). The public has also increased their awareness around the impacts of the seafood industry, leading the industry to begin adopting more sustainable standards for production (Belton et al., 2009). The intersection between public awareness and policy development for the seafood industry requires ANR students have the skills to critically engage with these socio-scientific issues to increase their efficacy in problem solving and generating solutions for sustainability (Onwu & Kyle, 2011; Ruth et al., 2018; Skladany et al., 2007; York et al., 2019).

Pedagogical tools that make explicit the relationship between humans and the environment can enhance science education by involving the cognitive and affective domains of experience (Littledyke, 2008). One method for enhancing cognitive and affective connections with scientific ANR content is hypothetical case scenarios (HCS). HCS, also known as choose-your-own-adventure scenarios, are a broadly used teaching method (Ferreri & O'Connor, 2013; McKim &

Torres, 2010) and have been used as part of the gamification of learning process intended to enhance student engagement within the classroom (Bechkoff, 2019). HCS tools for teaching presents students with realistic scenarios and then provides an opportunity for them to support and justify their decisions within a structured group environment (Scott et al., 2021). By using HCS, participants are presented with a choose-your-own-adventure style of branching scenarios (Sider et al., 2021). Despite the potential utility of such an educational approach, little is known about using HCS to teach about complex issues related to ANR, making it worthy of exploration as a potential pedagogical tool for improving learner engagement in the learning process (Bechkoff, 2019).

Conceptual Framework and Literature Review

The conceptual framework for this study was systems thinking, as operationalized by Rutherford (2019). For the purposes of the present study, systems thinking was conceptualized to include characteristics generally associated with systems thinking in educational settings. According to Brandstädter et al. (2012), "*structural system thinking* is the ability to identify a system's relevant elements and their interrelationships, altogether determining the system's framework" (p. 2148) and "*procedural system thinking* is the ability to understand the dynamic and time-related processes that emerge from the systems' structure, particularly occurring in within systems' elements and subsystems" (p. 2148). Therefore, systems thinking included both the ability to discern the relevant elements and relationships between system parts as well as the time related effects associated with events within a system.

In an increasingly interconnected and unpredictable world, systems thinking is a skillset that can identify the root of complex problems and propose interventions to improve outcomes (Rutherford, 2019). Systems thinking approaches can be described as those that emphasize the interdependence of component parts of a dynamic system and their interactions with other social, cultural, environmental, economic, political, and behavioral systems (Mahaffy et al., 2018; Sanders et al., 2021). Pauley et al. (2019) called for ANR scholars and practitioners to "foster complex adaptive systems thinking among their stakeholders through education and outreach" (p. 142). Experts have attempted to define systems thinking through multiple disciplinary lenses (Arnold & Wade, 2015) to reframe the ways in which problems are viewed and solutions proposed (Cabrera et al., 2008). Arnold and Wade (2015) present systems thinking as an increasingly necessary skill set required for leaders in a complex, interconnected world and defined it as "a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects" (Arnold & Wade, 2015, p. 675).

Systems thinking has been used to improve the quality of professional programs (Dolansky et al., 2020), influence policy-makers (Haynes et al., 2020), and enhance student learning and abilities to tackle complex problems in STEM education (York et al., 2019). One method through which systems thinking can be understood is with the use of systems archetypes, which are commonly recurring behavior patterns within various systems (Rutherford, 2019; Senge, 1990). Archetypes, once understood, can be recognized within a situation and allow for systems thinkers to map out the scenario according to the archetype's characteristics and more deeply investigate a problem (Rutherford, 2019). The three archetypes of interest in the current study were: the tragedy of the commons, fixes that backfire, and accidental adversaries. The tragedy of the commons archetype occurs when a common, collective resource becomes depleted as a result of individuals or groups taking too much, demonstrating how the actions of individuals can affect the collective good (Rutherford, 2019). The fixes that backfire archetype occurs when a problem keeps repeating itself despite efforts to fix it. Often, unintended consequences occur as a result of competing or opposing long- and short-term needs (Rutherford, 2019). The third archetype, accidental adversaries, the unintentional action of one partner negatively affects or harms the interest of another partner, leading the two to develop into adversaries (Rutherford, 2019).

Systems thinking has received much attention within science education research (Mahaffy et al., 2019; Yoon et al., 2018; York et al., 2019). Recommendations in the literature suggest incorporating systems thinking into educational practice, but few studies exist demonstrating the successful integration of systems thinking into the classroom (Gilissen et al., 2020). To date, few studies have examined how systems thinking archetypes may be integrated into a formal classroom environment as an educational tool. Even fewer studies couple systems thinking archetypes with a case study method. Generally, systems thinking archetypes or approaches are applied to the analysis of data rather than in the educational intervention itself. Bardodel and Haslett (2004) used systems archetypes to develop case studies to facilitate learning in the classroom, though they examined different archetypes proposed by Senge (1990). Systems thinking HCS approaches have been found to be complimentary to experiential pedagogy (Bardodel & Haslett, 2004), and experiential learning is a foundational tenet of agricultural education (Baker et al., 2012). Thus, the current study addressed an existing gap within the literature, specifically considering the efficacy of a case-based systems thinking approach applicable to ANR-related disciplines.

Purpose & Research Questions

The purpose of this study was to explore the educational potential of HCS when students are learning systems thinking content. Three research questions guided the study:

1. What responses did participants provide for each hypothetical case scenario?
2. To what extent did participants incorporate systems thinking content in their responses to the hypothetical case discussion?
3. How did participants describe the experience of using hypothetical case scenarios method?

Methods

The current study used a mixed-methods approach to address the study's research purpose and questions. The purpose for using mixed methods was complementarity, which seeks broader and more comprehensive understandings of a phenomenon by using complementary methods to explore various dimensions of the phenomenon (Greene, 2007). The current study followed an embedded mixed-method research design in which a focus group session followed the dissemination of a quantitative survey instrument using identical system thinking based scenarios (Greene, 2007). The mixed-method design also allowed for triangulation of the data to enhance the trustworthiness of findings (Lincoln & Guba, 1985). The sample for the study included students enrolled in an agricultural leadership course within the University of Georgia Department of Agricultural Leadership, Education, and Communication.

Instrument Development

Quantitative HCS Survey Instrument

For the quantitative portion of the study, an instrument was administered using the Qualtrics online survey tool. As such, the HCS with various system thinking archetypal scenarios and choices were presented to each participant. The case study was structured such that participants were presented with a scenario and then two potential choices. Each choice then branched into a secondary set of two options. Therefore, two sets of choices were presented, resulting in four potential outcomes. After reviewing each scenario and progressing through two sets of choices for each scenario, the participants received descriptions (one out of four possible) of the outcome of their choices within each scenario. The first scenario presented a hypothetical case related to the decline of the population of Atlantic Cod in a coastal community. Content for the case was developed from real scenarios (Brodwin, 2015; Cudmore, 2009; Food & Water Watch, 2010). This scenario was developed to represent the tragedy of the commons systems thinking archetype described by Rutherford (2019). The second scenario, modeled after Rutherford's (2019) fixes that backfire archetype, described a medium-sized oyster farming operation deciding between relocating or expanding their operation in the face of negative environmental impacts. Content for this case was adapted from real events (Kraft, 2017; Petrolia & Walton, 2018; Sink et al., n.d.; Tallis et al., 2009). The last scenario presented a case of a community planning commission deciding whether to invest in the local tourism or local fishing industry, developed from real world scenarios (Baynes, 2021; Coral Reef Alliance, 2021; Dance, 2019; National Ocean Service, 2021; Sustainable Travel International, 2019). The survey instrument also asked respondents to self-identify according to demographic questions related to age, gender identity, race/ethnicity, whether the participant grew up in a rural, suburban, or urban environment, whether or not they grew up in a coastal community, any dietary preferences or restrictions they had that might impact their perception of seafood, student classification, and college enrollment. Prior to dissemination, the instrument was reviewed for face and content validity by a panel of experts in agricultural communications, agricultural leadership, extension education, natural resources and aquaculture, and quantitative research methods.

Qualitative Focus Groups

A focus group protocol was developed to allow participants an opportunity to discuss each scenario and the outcomes presented in the quantitative HCS survey instrument. Questions in the focus group protocol related to a systems thinking archetype for each of the hypothetical scenarios in the survey instrument. The focus group protocol was assessed for face and content validity by a panel of experts specializing in agricultural communications, agricultural leadership, and program evaluation.

To begin, a moderator provided participants with a brief definition of the archetype presented in one of the hypothetical scenarios and they were asked to raise their hands to identify which outcome(s) they selected in the scenarios. Participants were then asked "knowing there were different possible results, how did you go about making the decisions you did?" Once group members discussed this question, a second moderator passed out a printed version of the entire HCS so participants could see the range of possible outcomes. Participants were given one minute to read through the handout and then asked the following questions: "What did you expect to happen?"; "How did your expectations differ from what played out in the scenario?"; and "Knowing what you know now, would you make any different choices?" This process and line of questioning was repeated for the subsequent two scenarios. At the end of the session, participants were asked to summarize their experience with the survey instrument and focus group session in one sentence. The moderator went around the room and asked each participant to respond to this question in turn.

Data Collection and Analysis

Data were collected for both the HCS survey and focus group sessions on November 10, 2021. The course instructor advised students prior to the focus group session that they could voluntarily participate in the focus group session on the specified day and the instructor remained absent from the focus group sessions to increase confidentiality for the participants. The study was approved by the University of Georgia Institutional Review Board (Protocol #00004479).

Participating students were randomly assigned one of three focus group sessions once they arrived in the classroom. After a brief overview of what to expect in the sessions, the three groups were assigned to individual rooms. Once participants arrived in their assigned room they were provided an identification sheet with an identification number and a place to record the outcomes they selected for each hypothetical scenario. This sheet was used for reference during the focus group session. Quantitative data were analyzed descriptively using frequencies and percentages.

Numbers of participants in the focus group sessions ranged from eight to 10. Participants were first asked to complete a survey once seated in the room. The survey was disseminated via Qualtrics. The survey instrument consisted of three hypothetical case scenarios related to the seafood industry and demographic questions. Participants were prompted to select one of two offered options for the described case-based scenario. After completing each scenario participants received the results of their choices including a description of the hypothetical outcome explaining the impacts of their selections and any consequences that occurred based on the choices.

The qualitative portion of the mixed-method study consisted of focus group sessions with the participants immediately after completing the survey instrument. Focus groups are group discussions designed to explore individual and collective views and experiences of a specific phenomenon, specifically using group interaction as data (Kitzinger, 1994). Due to the social interactions within the focus group, a social constructivist perspective underlies the data collection method (Merriam & Tisdell, 2015). Participants could hear others' responses and had an opportunity to expand comments beyond their own original responses, considering their own views in the context with those of others (Patton, 2014).

The focus group sessions lasted an average of 60 minutes. Three focus group sessions were conducted simultaneously in person. Each focus group had a primary moderator, a secondary moderator, and a notetaker. All focus groups used the same moderator guide. At the conclusion of each focus group session, a notetaker read a summary of participants' statements to allow for member checking further enhancing the trustworthiness and rigor of the data (Lincoln & Guba, 1985).

Focus group data were transcribed verbatim, imported into MAXQDA for analysis, and analyzed through inductive coding using the constant comparative method (Glaser & Strauss, 1967), by which themes were derived from the data itself rather than from predetermined theory (DeCuir-Gunby et al., 2011). Two authors open coded the data followed by axial coding to make connections between codes derived from the open coding process (DeCuir-Gunby et al., 2011). The two coders created a codebook to document the development of codes and agreement between codes (DeCuir-Gunby et al., 2011). The coders engaged in peer debriefing to enhance the trustworthiness of the data (Lincoln & Guba, 1985).

To aid in the interpretability of findings a subjectivity statement is also provided as recommended within the literature (Preissle, 2008). The primary coder was pursuing a doctoral degree in science communication and program evaluation in the department in which the course sample was taken. She specifically focuses on identity-oriented communication and evaluation in her research, with an emerging research inquiry about systems thinking around agricultural innovations. The second coder on this manuscript was pursuing a graduate degree in agricultural and environmental sciences with an undergraduate degree and professional experience in agriculture, which may have affected their views on food systems when coding the data. The second coder also possessed an undergraduate degree from the institution at which the study was conducted that may have led to biases toward students based on their presumed identities within the university observed during focus group sessions; however, the second coder possessed no previous relationships with any of the focus group participants.

Participants

Twenty-five students participated in the study. A majority of participants were White (*n* = 16, 59.3%) and female (*n* = 15, 55.6%). Participants also identified as Black/African American (14.8%), Hispanic/Latinx (7.4%), and Asian (3.7%). Participants ranged in age from 18 (*n* = 2, 7.4%), 19 (*n* = 10, 37.0%), 20 (*n* = 5, 18.5%), 21 (*n* = 4, 14.8%), and 23 (*n* = 1, 3.7%). Participants represented all undergraduate classifications: first-year (*n* = 2, 7.4%), sophomore (*n* = 8, 29.6%), junior (*n* = 9, 33.3%), senior (*n* = 2, 7.4%), and other (*n* = 1, 3.7%). College enrollments included the College of Agricultural and Environmental Sciences (*n* = 16, 59.3%), the College of Business (*n* = 4, 14.8%), and the College of Arts and Sciences (*n* = 1, 3.7%). When asked what type of community in which they grew up, 3.7% (*n* = 1) of participants selected urban, 40.7% (*n* = 11) selected suburban, and 37.0% (*n* = 10) selected rural. In addition, a majority of participants did not grow up in a coastal area (70.4%) and had no dietary preferences or restrictions (55.6%). Other dietary preferences included vegetarian (*n* = 2, 7.4%) and other (*n* = 3, 11.1%; open-ended responses included allergy to nuts; no seafood; no dairy, pork, or gluten).

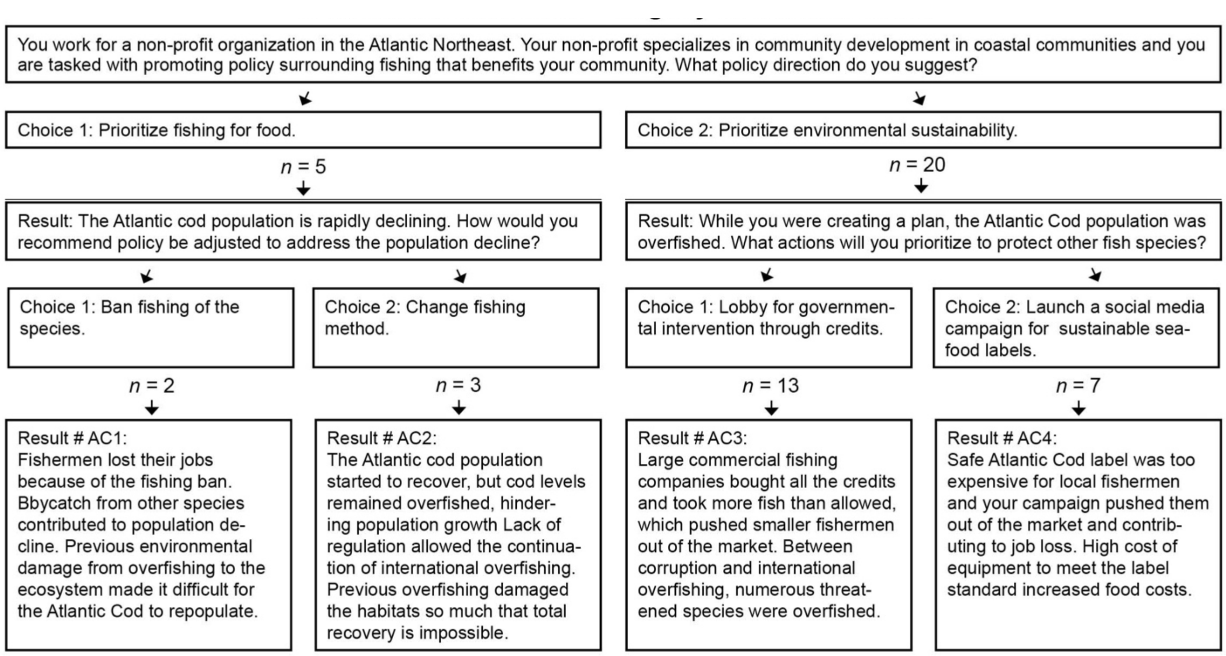
Results

RQ1: What responses did participants provide for each hypothetical case scenario?

Results used to answer the first research question were derived from the quantitative portion of the study and are presented below. Frequencies for the tragedy of the commons scenario (Atlantic Cod) indicated a majority of participants prioritized sustainability (*n* = 20) over an alternative option (*n* = 5) at the first choice stage. Based on the four potential outcomes associated with the secondary choice stage, the most participants (*n* = 13) selected lobbying for a governmental credit system as their preferred system intervention in their decision making (see Figure 1).

Figure 1

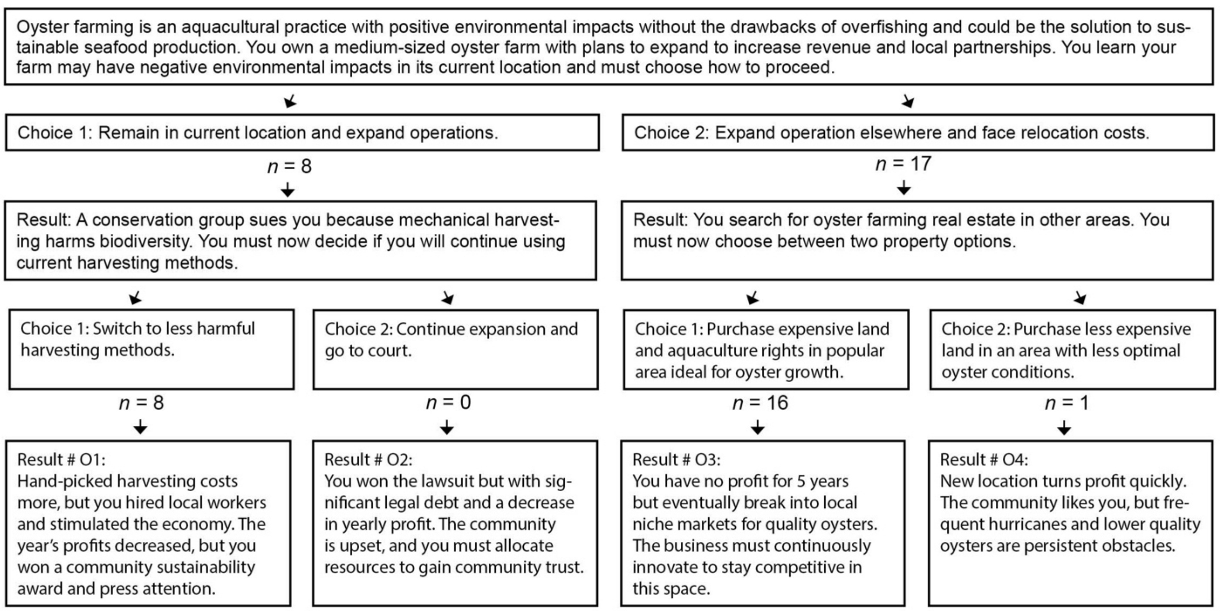
Tragedy of the Commons Scenario (Adapted from Brodwin, 2015; Cudmore, 2009; Food & Water Watch, 2010)



The second scenario, fixes that backfire, demonstrated participants' decisions related to moving or expanding an oyster farming operation facing potential environmental and economic impacts. At the initial choice stage, the majority of participants (*n* = 17) decided to expand their operation and face economic costs while prioritizing the environment. At the second-choice stage, the majority of participants decided to prioritize the quality of their product (*n* = 16), considering the long- and short-term economic impacts of their decision (see Figure 2).

Figure 2

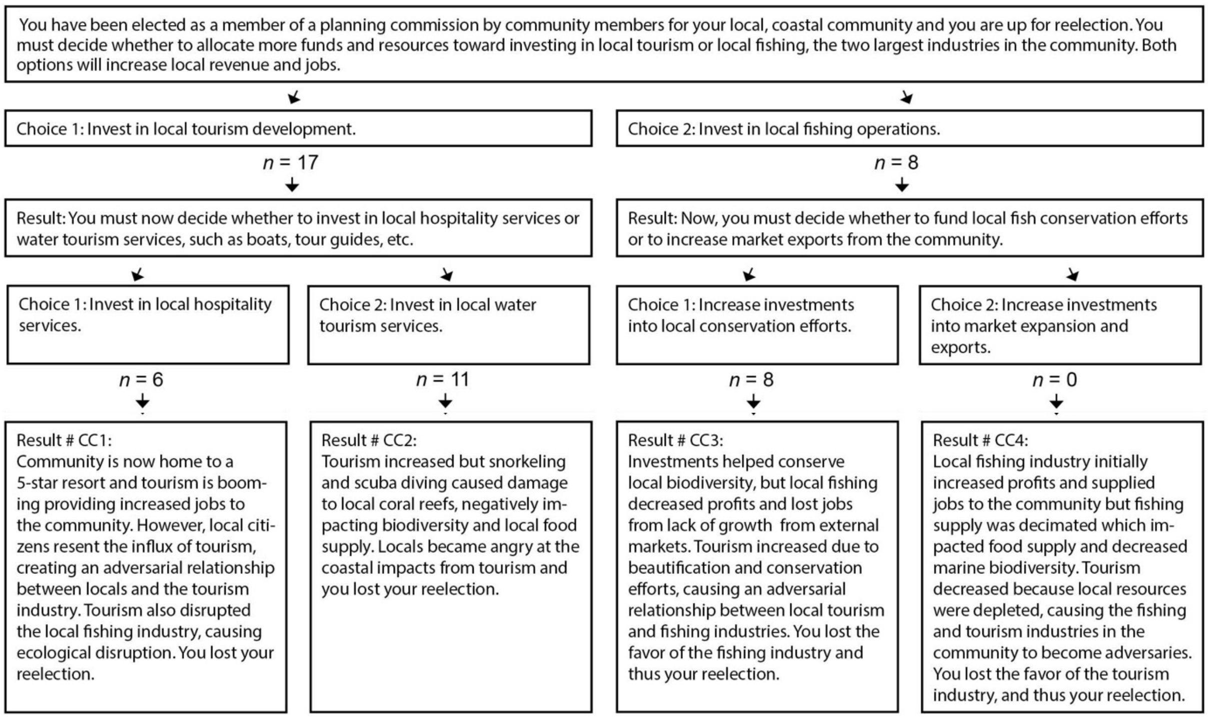
Fixes that Backfire Scenario (Adapted from Kraft, 2017; Petrolia & Walton, 2018; Sink et al., n.d.; Tallis et al., 2009)



The last scenario, accidental adversaries (see Figure 3), presented a decision between investing in local tourism or the local fishing industry. At the first-choice stage, the majority of participants chose to invest in local tourism (*n* = 17). At the second-choice stage, the majority of participants chose to invest in local tour guide training (*n* = 11).

Figure 3

Accidental Adversaries Scenario (Adapted from Baynes, 2021; Coral Reef Alliance, 2021; Dance, 2019; National Ocean Service, 2021; Sustainable Travel International, 2019)



RQ2: To what extent did participants incorporate systems thinking content in their responses to the hypothetical case scenario discussion?

During the focus group session, participants were provided descriptions of the underlying archetype for each scenario and then given an opportunity to respond to each scenario. Five themes were identified related to systems thinking in participants' responses: 1) *evaluating consequences*, 2) *evaluating risk*, 3) *considering long-term impacts*, 4) *imagined improvements*, and 5) *comparing the efficacy of various approaches*.

Within the first theme, *evaluating consequences*, participants expressed how they weighed different options in the survey based on potential consequences of the action. A participant in Focus Group (FG) 3 stated, "[t]his experience made me think about new consequences to certain choices and showed that most decisions often have unpredictable outcomes." Three subthemes were identified for the *evaluating consequences* theme: *negative and unintended* consequences, *balancing consequences*, and *acknowledging downsides*. Participants discussed how they were surprised by the unintended consequences of their choices: "This activity showed me that there's not a cut and dry, correct answer and that many of our choices have unexpected consequences that we can't always see ahead of time" (FG 2). In addition, participants discussed how they tried to balance the negative consequences with the positive consequences of a choice, as one participant explained:

> [My choices for the accidental adversaries scenario] ended up not at all working out. Because tourists came anyways, so the fishermen got mad. Then the fishing

> industry decreased because of the focus on sustainability. It ended up not working out at all, but ... that was the best happy medium. (FG 1)

Other participants acknowledged that most choices will be accompanied by downsides, as explained by one participant: "[i]n the end, everything will have a downside. Whatever decision we make, so you just want to do good, do what's best, what you think is best" (FG 1).

The second theme identified was *evaluating risk* as described by participants in selecting their choices in the survey instrument. When making decisions in the survey, as well as reflecting upon the choices they made during the focus group session, participants evaluated choices based on the perceived risk associated with each choice. For example, one participant explained,

> [For the fixes that backfire scenario,] I chose the more expensive one because of hurricanes and how drastic they are, they happen almost every year where I'm from. And it just ruins a lot of peoples' lives, so didn't want to go that way and just choose the safer option, more expensive but payoff and hard work. (FG 2)

Another participant stated, "I was like if I want to get to a higher level [in my business], I just need to take the risk and then see how it goes" (FG 2).

Considering long-term impacts was the third major theme identified, as students considered the long-term impacts of their choices on the economy, the environment, and the stakeholders. One student described their consideration of long-term consequences: "I think in the long run, it will be the most effective thing" (FG 3). Two subthemes were identified, *economics* and *environment.* Related to *economics*, one participant explained their thought process for one of the scenarios:

> [For the fixes that backfire scenario,] I was thinking more of the long-term results of "Yes, I might be in debt right now, but the rewards will show later." I was thinking about, especially with the high quality I was like, "If I have a high-quality oyster people are going to still keep coming to me because I have the best oysters out of everyone." (FG 1)

Many participants prioritized sustainability and the *environment* in their decision-making processes:

> I definitely just think that it's about thinking long-term and having what you believe and sticking to those core beliefs. For me, the environment is one of those things. And so, I definitely put profits under environment because if we don't have a planet, then nothing really matters. (FG 2)

Within the fourth theme, some participants *imagined improvements* they would make to the scenarios, indicating an expansion of systems thinking beyond the choices presented. One participant described how they would alter the choices in the scenario to provide a better outcome:

> [For the tragedy of the commons scenario,] I did environmental sustainability. But I feel like out of those two choices, I feel like there could have been a third choice that might've been a better option like maybe placing a temporary ban on the Atlantic Cod... (FG 2)

Within the final theme, participants *compared the efficacy of various approaches* after they learned about the consequences of their decisions in the survey instrument. One participant expressed:

> Just out of the choices that were given [for the tragedy of the commons scenario], I don't really think either one of them was very beneficial to what they were trying to achieve, but I went with the social media campaign. I don't really think that did very much good in the end, but with the governmental intervention credits, it pushed the local fishermen out of the market and then all the large companies bought it up. So really, either one is not the greatest solution. (FG 2)

RQ3: How did students describe the experience of using the hypothetical case scenario method?

Participants were asked to describe the overall experience of the survey and focus group session relating to the scenarios. Four themes were identified: *positive experience, challenged to think more deeply, enhanced crucial thinking,* and *eye-opening experience*. First, most participants perceived it as a *positive experience,* describing the HCS teaching method as "thought-provoking and informative" (FG 3) and a "fun [way] to have all these difference choices and see the different outcomes" (FG 1). For the second primary theme, participants indicated that the experience *challenged them to think more deeply* about the content as well as the consequences of decision-making for complex issues. One participant explained how the experience "made me think deeper about the issues" (FG 3). Another participant expressed,

> This activity was a good chance […] to use critical thinking to try to solve these scenarios and then even then, you realize that there's not necessarily a great answer, but I think it allows you to state your core beliefs to make the decisions that you think would be reflective of who you are. And even if the results aren't necessarily the best, you could still stick with what you believe.

A third theme was how the experience *enhanced critical thinking* "about your actions and how they can trickle down… how it affects the whole population" (FG 2). Another participant stated, "this activity showed me how there's no perfect solution to the problems that we're faced with. You just have to go with what you value and what best supports that community" (FG 1).

For the fourth theme, participants described the HCS teaching method as an *eye-opening* experience. One participant described the experience as "pretty eye-opening, [as I] don't often think about the seafood industry…it's very interesting to see how there's not one perfect solution, and we just have to be collaborative about finding the right solution" (FG 2). Other participants explained how the experience made them think about real-world scenarios they have never before considered: "It was eye-opening. I'm 19... I'm not in charge of a community or a town. So, it's interesting to think about the decisions you make and how they can impact such a large group of people in the environment" (FG 2).

Conclusions and Recommendations

The current study highlights the pedagogical potential of using the HCS teaching method in ANR disciplines and classrooms. Overall, participants were highly involved in what they described as a positive experience and the results indicated a high degree of systems-thinking capacity demonstrated in their responses in the focus group sessions. While participants were not exposed to systems thinking as an academic concept prior to the study, the results indicated HCS have the potential to foster learning environments which encourage systems thinking related to decision-making for ANR topics. Participants demonstrated systems thinking approaches within the HCS experience through evaluating consequences of their choice in the survey instrument, evaluating the perceived risk associated with each option, considering long-term impacts from both an economic and environmental perspective, and comparing the efficacy of various approaches. Additionally, some participants moved beyond the limited options presented in the scenarios to imagine how they would make changes to the choice options to improve the outcomes, and limit the unintended consequences, of each choice.

As a pedagogical technique, it is important to examine the experience of the HCS itself. Participants described the experience as positive, thought-provoking, informative, and eye-opening. For others, it provided an opportunity to explore a topic to which they otherwise would not have been exposed. Findings suggest HCS teaching methods for systems thinking and ANR issues has the potential to increase students' critical thinking skills for complex, socio-scientific issues (Fensham, 2014). ANR disciplines, and agricultural education specifically, have been called to incorporate systems thinking and adaptive processes to foster sustainable development through educational practices (Andenoro et al., 2016; Pauley, 2019). While the current study focused specifically on the seafood industry due to the complex social and ecological issues embedded within the industry and its stakeholders (Mazur & Curtis, 2006), the HCS method may be used to foster dialogue, collaboration, and systems thinking for other ANR topics to enhance experiential pedagogies to educate for complex issues (Fensham, 2014; Onwu & Kyle, 2011).

Several limitations exist for the current study. First, the sample is only from one course in the College of Agricultural and Environmental Sciences at a single large public university. Thus, results of the descriptive study should not be generalized beyond the sample. Second, the focus for the case studies was an unfamiliar topic for most learners. This may have influenced the observed results. Replicating the approach with content familiar to participants is recommended to further examine the role of systems thinking in the learning process. Despite the noted limitations, readers may wish to consider the findings to glean pedagogical potential from the HCS method to apply to their own educational contexts. Other considerations for implementing the HCS method include developing a scenario and discussion setting conducive to the busy schedules of undergraduate students. A few students found the experience long and struggled contributing to, or engaging in, the discussion following the scenarios, so adapting the HCS method for various learning styles may increase the potential systems-thinking capacity development for students.

Future research should examine students' systems-thinking capacity and analyze the relationship between this capacity and their choices and outcomes of an HCS experience. A potential outcome from such analysis could lead researchers and educators to further develop HCS that can elicit specific systems thinking capacity development for students focused on developing more specific systems thinking structures, such as structural and procedural systems thinking (Brandstädter et al., 2012). In addition, research could examine students' systems-thinking capacities with other scales related to ANR concepts, such as consumer values, perceptions of climate change, or others related to the wicked problems facing agriculture and the environment.

Responding to Pauley's (2019) call for ANR educators to "foster complex adaptive systems … through education and outreach" (p. 142), the use of HCS offers a novel approach and proposed set of methods to increase the pedagogical reach of ANR disciplines to help educate around complex, wicked problems. The literature contains a limited number of examples coupling systems thinking with HCSs (e.g. Bardodel & Haslett, 2004), indicating a gap in scholarship surrounding this potentially beneficial educational approach. The current study demonstrated the engagement and critical thinking enhancements that accompanied the HCS experience and the systems thinking demonstrated by the participants.

With the increasingly complex issues discussed within ANR disciplines, educators are tasked with teaching skills to help students navigate and solve opaque and multipart problems (Fensham, 2014). As the nexus between public awareness and policy development becomes increasingly intertwined in an information-dense society (Ruth et al., 2018), ANR education students must be able to critically engage with socio-scientific issues to increase their efficacy in problem solving and generating solutions for sustainability (Onwu & Kyle, 2011; Ruth et al., 2018; Skladany et al., 2007; York et al., 2019). Thus, educators must develop adaptive pedagogical tools to respond to the complex needs of ANR students. The results present a proof of concept indicating HCS may be a promising opportunity for experiential, adaptive learning processes to further increase students' critical thinking and dialogical skills in the classroom and beyond.

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