Understanding the Impact of a Low-Commitment Scientific Innovation Modules on Undergraduate Biology Students' Grit, Retention, Biology Interest, and Biology Self-Efficacy

By

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ABSTRACT

Introducing innovation courses to engineering and computer science has been shown to increase retention and interest in the discipline. However, the impacts of innovation interventions have not been explored in biology undergraduates with respect to grit, retention, biology interest, and biology self-efficacy. This study examined whether introducing scientific innovation modules increased the grit, retention, biology interest, and biology self-efficacy of undergraduate biology students.

Online modules that took approximately 20 minutes per week over four weeks were added to the learning management system for an introductory biology lab course and a course on Careers in Biology. Half of the students in each course completed online modules on scientific innovation while the other half completed modules on financial literacy as a comparison group.

This mixed-methods study used pre- and post- surveys, institutional data, and interviews to test four hypotheses: exposure to a scientific innovation course would increase biology undergraduates' i) grit, ii) retention, iii) biology interest, and iv) biology self-efficacy.

Pre- and post- survey results (N=139) do not support the hypotheses, with no significant main effects of group (completion of treatment vs comparison modules) or interactions between group and time (indicating an impact after the intervention but not before) but other interesting effects were observed. Overall, students in the Careers in Biology course responded to the treatment as hypothesized whereas students in the introductory biology lab course did not respond as predicted. Underrepresented minority students responded positively to the treatment with respect to biology interest. Another finding is that students generally lost interest in biology over the course of the semester but students who expressed an interest in entrepreneurship did not experience this loss of interest in biology. Institutional data showed that pre- scores for biology self-efficacy were significantly lower for those who later ended up failing a course that semester than those who did not fail During the interviews, students articulated that they preferred to be exposed to scientific innovation and diverse career options during their freshman or sophomore years., Job satisfaction and helping the world were also important factors for choosing their major.

This study provides insight into the impacts innovation courses on biology undergraduates. While the hypotheses were not supported, the observed effects may inform the development of programs to foster grit, retention, interest, and self-efficacy as well as future scientific innovation courses for biology undergraduates.

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A Thesis

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In Partial Fulfillment of the Requirements for the Degree

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## Chapter 1: Introduction

There is a retention problem within the life sciences, especially biology; roughly half of all incoming biology students will switch majors by their senior year (American Association for the Advancement of Science [AAAS] 2011). In addition, roughly half of those polled with a bachelor's degree in the life sciences do not work in a related field (U.S. Census Bureau 2014). For those who do become life science professionals, there is often a lack of training in realizing the potential commercial opportunities of their work (Brown & Kant 2008).

Scientific research generates new knowledge, and this knowledge can be leveraged into new products or methodologies. Products or services solve a problem or alleviate frustration, much like how scientific research addresses questions. While biotechnology has taken off in recent years as a field ripe for innovation, there are other sectors of biology that have immense potential as well. Fields such as microbiology and mycology are well positioned for innovation in industries such as bioremediation and biofuels. Environmental and conservation biology can also develop products or methods to combat climate change or protect vulnerable species and habitats. Botany can innovate for the textile and agricultural markets. Scientists are natural innovators, but their research does not always get translated to a product or service, as universities historically have not trained their students and faculty to recognize the potential commercial opportunities for their research.

Researchers have acknowledged the necessity of this type of education in the sciences. Faculty in biotech programs have accepted and written about the importance of entrepreneurship education for graduate students (Brown & Kant 2008; Crispeels et al., 2008; Meyers 2014). Yet very few studies have been conducted on biology undergraduate populations and none have looked at the impact of educating biology students about entrepreneurship on their biology interest, retention, and self-efficacy. Studies on students in other disciplines, specifically engineering and computer science, show that entrepreneurship education is positively impacting motivation and retention in other disciplines (Bilen et al. 2005; Matthew et al. 2004; Ohland et al., 2013). In addition, the literature shows that illustrating the applications of science or explaining how to leverage knowledge for communal benefit as well as values affirmation increases motivation, achievement, and retention in underrepresented minority students (Estrada et al. 2016; Jordt et al. 2017).

Successful, "high commitment" entrepreneurship training programs for undergraduates do exist but these typically have their own courses and require a lot of effort by students. Some examples of these programs are East Carolina University's First Year Experience Program for their honors college (Chaney et al., 2020; Chaney et al., 2021) and the Penn State University's engineering entrepreneurship minor program, E-SHIP (Bilen et al., 2005). Programs like these are seeing successful impacts in motivation and creativity (ability to apply their knowledge in novel ways) (Rzasa et al. 2004; Bilen et al. 2005). In addition, the National Science Foundation has funded the creation of the Community of Neighboring and National Entrepreneurial Centers and Trainees (CONNECT) Network with the goal of integrating biosciences entrepreneurship with undergraduate biology education in 2023 (*Connect Network* 2023).

Entrepreneurship education is ripe for showing the applications or communal benefits of science, but entrepreneurial education studies face issues with acceptance. Multiple literature reviews have called for more rigorous studies within entrepreneurship education literature; most of the literature involves studies that lack a comparison group and use a single test design as opposed to a pre- and post-test (Newman et al., 2019; Pittaway & Cope 2007; Rideout & Gray 2013).

The lack of rigor, accepted format, or content, along with results that sometimes are contradictory, have created an uphill battle for entrepreneurship education and research to be accepted in STEM disciplines (Newman et al., 2019; Pittaway & Cope 2007; Rideout & Gray 2013). This study looks to fill this gap in the literature and evaluate potential connections between entrepreneurship education and biology self-efficacy, interest, and retention through the lens of the Social Cognitive Career Theory Framework (Lent, Brown, & Hackett 1994; Lent, Brown, & Hackett 2002).

**Social Cognitive Career Theory**

The Social Cognitive Career Theory (SCCT) describes a model to explain the variance in intended and actual academic persistence among STEM majors (Lent et al., 2003; Lent et al., 2005; Lent et al., 2008). The most influential predictor of the model is self-efficacy (Gore and Leuwerke 2000; Lent et al., 2008), which is defined as the confidence in one's own ability to perform a task or obtain a specific outcome (Bandura 1986). Other predictors of STEM persistence include barriers (mental, physical, social, or monetary barriers to science), support (mental, physical, social, or monetary support in pursuing or persisting in science), outcome expectations (the expected outcome(s) or benefit(s) of entering and staying in science), and interests (personal interest in scientific concepts or a career that requires a science degree).

According to the SCCT model, increasing self-efficacy should positively influence outcome expectations, interests, and major choice goals. Studying biology and pursuing a degree in biology are considered major choice goals that are influenced by the career the student wants. This positive reinforcement of these predicting factors of SCCT should result in renewed and or reinvigorated interest in biology and retention of the student. Entrepreneurship education may also result in an increase in positive outcome expectations by showing students a new career option within biology, and that their ideas can not only make money but have a positive impact on the world whether it be for the environment, humans, or animals. Students can be agents of change by impacting causes they care about through synthesis of biological concepts and their ingenuity to create new products or methods. Through increasing self-efficacy and positive outcome expectations of biology students, I hypothesize we will see an increase in student interest and persistence when students are exposed to entrepreneurship education, due to the mechanisms described by Social Cognitive Career Theory (see Figure 1, p. 751 in Brown, Lent, & Hackett 2002). Self-efficacy and outcome expectations are predictors that entrepreneurship education may be able to influence, and these two predictors have been shown to influence interest and persistence (Lent et al., 2008). A study on first generation college students in engineering has shown that outcome expectations have a significant influence on this population's persistence intentions (Garriott, Navarro, & Flores 2017); this data is interesting as previous studies on engineering students have shown outcome expectations have minimal impact, but those samples were of predominately white, non-first-generation students (Lent et al., 2003).

**Transformative Learning**

Undergraduate students have preconceived notions from society of the qualities that entrepreneurs have and resources they need (Neergaard et al., 2020). Successful interventions must change the preconceived notions of entrepreneurship that students have and replace it with correct conceptions of entrepreneurship, the resources available to entrepreneurs, and the skills required to be an entrepreneur (Neergaard et al., 2020).

In addition, characteristics necessary for entrepreneurship, like innovation, risk taking, customer orientation, and translation of results from "lab" into life (Bilen et al., 2005), are often not emphasized in schools. Rideout and Gray (2013) succinctly describe how the United States does not educate for these skills:

> *In the United States, primary school teachers typically discourage creativity, independence, and a questioning approach to life in their classrooms. Instead conformity is preferred and thought diversity is undervalued. At the post-secondary level, schools and universities generally focus on preparing students to be good employees of organizations as their only career choice*. (p. 330)

This educational idea of conformity fosters mindsets that discourage the innovation and risk-taking necessary for entrepreneurship, which also happens to be like the mindset needed for scientific research. A focus on entrepreneurial education with undergraduates in the sciences may help to prepare students to succeed, become desirable job applicants, and foster innovation. This focus also may transform the way these students perceive themselves, the scientific process, and the opportunities available to them. Therefore, it may influence a student's likelihood of persisting in a science major.

**Research Goals and Hypotheses**

The aim of this study was to determine the impact of exposing undergraduate biology students to scientific entrepreneurship on their biology self-efficacy, interest, grit and ultimately retention in biology based on the Social Cognitive Career Theory framework. This study was designed to fill gaps in the literature by focusing on i) an understudied population for entrepreneurship, the undergraduate biology student population, ii) the unexplored response variables of biology self-efficacy, interest, grit, and retention, and iii) a rigorous research design. To do so, I exposed half the participants of biology students (my treatment group) to online modules about scientific entrepreneurship education and the other half of my participants (the comparison group) to online modules about financial literacy, a topic that was not expected to impact my response variables. Both qualitative and quantitative data in the form of surveys, interviews, and institutional data on enrollment, grades and academic major were collected. The specific hypotheses are:

1) *Students who experienced entrepreneurship education will have higher* ***grit*** *as compared to students who did not receive entrepreneurship education*. Entrepreneurs, like scientists, experience failure often. By showing this to students and explaining that failure is a normal part of research as well as product development they will be more accepting of failure and persist knowing that failure is normal. Additionally, showing students how to apply their knowledge through design thinking can provide intrinsic motivation to persist so they can make the world a better place.

2) *Students who experienced entrepreneurship education will have higher rates of continued enrollment from the first to the second semester of introductory biology for majors (i.e.,* ***higher retention****) as compared to students who did not receive the entrepreneurship education intervention*. I proposed that giving students the tools to apply their knowledge to create new products or methods and exposing them to the idea of starting their own business and being their own boss would reinvigorate the drive within them to pursue biology and persevere through difficult courses.

3) *Students who experienced entrepreneurship education will have more* ***interest in the biology major*** *as compared to students who did not receive the entrepreneurship education intervention*. I anticipated that by broadening students' awareness of biology career opportunities and showing them how they can use biology and entrepreneurship to solve problems, they will be more interested in biology and how they can leverage it for their personal interests.

4) *Students who experienced entrepreneurship education will have increased **biology self-efficacy** as compared to students who did not receive the entrepreneurship education intervention*. Entrepreneurship teaches students how to leverage their education to create products or solutions for real-world problems. Through synthesizing and applying their knowledge, I thought that students would feel more confident in their academic skills and mastery of biological concepts.

# Chapter 2: Methods

To test these hypotheses, biology students were recruited to complete entrepreneurship (treatment) or financial literacy (comparison) modules. Changes in students' grit, retention, biology interest, and biology self-efficacy were measured using a combination of surveys, interviews, and institutional data. This study used an explanatory sequential study design in which qualitative results (interviews) are being used to help explain quantitative (survey and institutional) results. The human subjects research was approved by an institutional review board (UMCIRB 22-000708).

## Study Population

This study consisted of undergraduates from East Carolina University (ECU) enrolled in the courses Careers in Biology (BIOL 1120) and Principles of Biology 1 Laboratories (BIOL 1101) during Fall 2022. Biol 1120 is a required course for all students intending to complete a Bachelor of Arts in Biology at ECU while Biol 1101 is a required course for all students intending to complete a range of science majors at ECU, including a Bachelor of Arts or a Bachelor of Science degree in Biology. All students enrolled in each of these courses were asked to participate in this study (~700 for BIOL 1101 and ~50 for BIOL 1120). Completion of the intervention modules and surveys were required course assignments in Biol 1120 (though students were not required to consent to have their data used for research purposes and could complete an alternate assignment). Extra credit was offered to students in Biol 1101 who completed the modules and surveys (though students could receive extra credit through an alternate assignment). I was left with a sample size of $n$ = 139 after cleaning the survey data by removing entries who answered less than 50% of the questions or anyone who answered the attention checks (see description of survey below in Data Collection section) incorrectly.

Students under the age of 18 as well as anyone who did not consent to participate in the research were provided with an alternate assignment not used for research.

**Intervention**

This training was a "low commitment" intervention, in that it was added into existing biology courses in the form of short, online modules that students could complete outside of course time over the span of one month rather than a full course over a semester or multiple courses throughout an academic career. The intervention was administered via Canvas by Instructure, an online learning management system. Each module consisted of a short quiz at the end to track which students completed the module and whether they learned the material or not. This evaluation was meant to determine if the students truly experienced the intervention instead of clicking through it for completion only. The intervention was designed to take place over one month with students completing one module a week, requiring approximately 20 minutes to complete each module. Roughly half of the students completed modules about entrepreneurship in STEM while the other half completed modules about financial literacy, for comparison. Students in 1120 were assigned to each group by assigning every other person to the comparison group within the roster of the course. Students in 1101 were assigned to each group based on their section. Every other section number was assigned to the comparison group, however, there was an odd number of sections, so the treatment group has one extra section compared to the comparison group. The treatment and comparison modules were designed to function similarly and take approximately the same amount of time and effort to complete.

**Entrepreneurship Modules**

With entrepreneurship education being a rather fledgling field, there are no standards of what information should be included and topics can vary substantially from university to university. I developed the content of this entrepreneurship intervention based on the current literature, NSF's I-CORPS program (https://www.nsf.gov/news/special_reports/i-corps/index.jsp), Dr. Mike Pape's Startup Staircase® (M. Pape, personal communication, August 2018), and my experience as an associate consultant with University of Central Florida's Small Business Development Center (https://sbdcorlando.com). The modules were designed to expose students to the concept of commercializing their ideas while keeping it short and engaging by not going too in depth on business topics. I focused on four subjects: Inspiration and Motivation, Design Thinking, Intellectual Property, and Available Resources. Subjects such as finances, business models, and pitching were not covered in the treatment modules.

To incorporate the ideas of inspiration and motivation into the first entrepreneurship module, I interviewed STEM entrepreneurs; through showcasing their journeys, I illustrated to students that their ideas can turn into products that have a real impact on the world. I also highlighted growing fields or areas of concern that are ripe for entrepreneurship such as microbiology, biotechnology, conservation biology, bioremediation, and agriculture. This module is intended to show students that entrepreneurship or "being your own boss" is a viable career path in the sciences, and you don't have to run the company yourself or even be involved; you can develop the technology for others to commercialize for you.

In the second entrepreneurship module, I followed the Design Thinking model created by the Hasso-Plattner Institute of Design at Stanford University (Doorley et al., 2018) which is comprised of five steps: Empathize, Define, Ideate, Prototype, and Test. Design Thinking is an established process to designing solutions that is widely used in the innovation space and is sometimes referred to as Human-Centered Design (Doorley et al., 2018). Designing with the end user in mind was compared to research and the scientific process. The remainder of the Design Thinking module focused on defining the problem once we have empathized with the client experience. This process was also related to its corresponding step in the scientific method: ideating or brainstorming solutions (hypothesizing), prototyping (experimental design), testing (running the experiment). It was noted that like science, design thinking is an iterative process and innovators must go back and forth between steps, like a scientist revising hypotheses based on the data and then retesting. Another similarity between design thinking and the process of science that was featured in this module is an emphasis on team science (National Research Council 2015). Entrepreneurs typically form teams of individuals whose talents span the multiple disciplines required to design, test, and build. Science is becoming more multi-disciplinary, especially with respect to research (National Research Council 2015).

The third module of this intervention covered the six types of intellectual property (IP): patents, trademarks, copyright, design, database, and trade secrets. I explained what each type covers, how long they last, and how they protect you. I also briefly went over licensing as this is especially important from a research perspective since the university or business that hires scientists for research will own the intellectual property generated unless an agreement is explicitly made beforehand saying otherwise. Additionally, I reviewed Creative Commons licenses and what making something open-source means as these are also viable options for licensing or releasing products or methods.

The last module reviewed the entrepreneurship resources available to students both through the university and outside of it. Programs like the NSF's I-CORPS (https://www.nsf.gov/news/special_reports/i-corps/index.jsp), Blackstone Launchpad (https://www.blackstonelaunchpad.org), Hult Prize (https://www.hultprize.org), ECU's Pirate Entrepreneurship Challenge (https://business.ecu.edu/msoe/pec/), 3D printing lab (https://libguides.ecu.edu/3dprintinge), and the Crisp Small Business Resource Center (https://business.ecu.edu/msoe/crisp/) are all collegiate-only resources that provide invaluable mentoring and networking opportunities as well as monetary rewards. There are also public programs such as the Small Business and Technology Development Center at ECU (https://sbtdc.org/offices/ecu/), Small Business Innovation Research grants (https://www.sbir.gov), Small Business Technology Transfer grants (https://www.sbir.gov), and the North Carolina Biotechnology Center (https://www.ncbiotech.org).

**Financial Literacy Modules**

`For this study, the comparison group completed four modules on personal finance from Khan Academy (https://www.khanacademy.org) and were quizzed on the modules in the same format as the treatment group. The comparison modules were designed to look as similar to the treatment modules as possible and require approximately the same time commitment over the same duration of time. Financial literacy was chosen for the comparison modules because it is a subject that the students will gain value from yet distinct enough from biology and entrepreneurship that we did not anticipate it will influence biology interest, self-efficacy, grit, or retention in the major.

**Data Collection**

The participants took a pre-survey and then either completed the entrepreneurship education modules or comparison modules, followed by a post-survey. Exit interviews were conducted with a subset of individuals from the treatment and comparison groups to determine if the qualitative data supported the conclusions from the quantitative data. Finally, institutional data was collected on declared or intended major for Fall 2022 and Spring 2023, STEM course grades for Fall 2022, and course enrollment for Spring 2023. Data collection from students took place in the Fall 2022 semester and institutional data was pulled in Spring 2023 on students from the Fall 2022 data collection sample.

**Survey**

Pre and post surveys were administered online via Qualtrics to evaluate the impact of the modules on students' grit, intention to stay at the university (i.e., self-reported data on retention), interest in biology, and biology self-efficacy. The questions (Appendix F) included demographic items and those designed to reduce threats to validity, as well as items from the Short Grit Scale (Grit-S) (Duckworth & Quinn 2009), the Brief Index of Student Retention (Davidson & Beck 2021), biology interest questions, and the Biology Self-Efficacy Scale for Non-Majors (Baldwin et al., 1999). To validate the combined survey for my research questions and study population, three experts read and commented on the relevance of the questions to my research questions. In addition, a pilot of the survey was used during the Summer 2022 semester with Introduction to Biology I labs (BIOL 1101) to determine if there were any questions or problems with how the students answered the survey items. Finally, a think aloud procedure with seven students from the summer pilot session was conducted to determine if the students perceived the survey items in the way they were intended.

The resulting survey had 4 subscales (retention, self-efficacy, biology interest, and grit) plus demographic questions and questions about the student’s background familiarity with entrepreneurship (Appendix F). There were 65 total items, and each item associated with the four subscales was answered on a 5-point Likert scale. To ensure that each of the expected four subscales were internally consistent with my study population, I calculated the reliability statistic, Cronbach's alpha. The subscales of self-efficacy (alpha = 0.952), biology interest (alpha = 0.789), and grit (alpha = 0.713) had high internal consistency. The retention subscale was less consistent (alpha = 0.421), in which the last two items seemed to be less consistent with the other three retention items.

The Short Grit Scale (Grit-S) is a modification of the original 12-item grit survey, Grit-O, to create a shorter, more efficient scale (Duckworth & Quinn 2009). The authors identified 8 items from the original scale with the best predictive validity across the samples from the original Grit-O study and ran confirmatory factor analysis as well as tested the predictive validity in two novel samples (Duckworth & Quinn 2009). The scale showed acceptable internal consistency with alpha values ranging from .73 to .83. Confirmatory Factor Analysis was run using the two-factor model and showed that two factors, Consistency of Interest and Perseverance of Effort were first-order latent factors that loaded on the second-order latent factor Grit. Structural Equation Modeling was run on the West Point Class of 2008 and fit indexes suggest a good fit $\chi 2$ (19, N = 1,218) = 106.36, $p < .001$; RMSEA = .061 (90% confidence interval [CI] = .050–.073), CFI = .95. When compared to the Grit-O scale the Grit-S scale is more efficient and psychometrically stronger (Duckworth & Quinn 2009). A meta-analysis on the Grit-S Scale confirms that the Grit-S scale is suitable for basic research but found that studies were inconsistent with participants outside the United States and among nonwhite participants thus warning against using the scale for clinical decision making (Rocha & Lenz 2022).

The Brief Index of Student Retention (BISR) is a modification of the College Persistence Questionnaire (CPQ). The goal of the authors of the BISR was to reduce the number of questions of the College Persistence Questionnaire while maintaining validity; this was done by using two regressions with re-enrollment status as the criterion (Davidson & Beck 2021). The authors were able to reduce the number of items to five items that accounted for 20% of the variance as compared to the CPQ which accounts for 22% of the variance. The instrument was also compared to the CPQ and was found to predict re-enrollment similarly: 83.16% for the CPQ and 82.51% for the BISR (Davidson & Beck 2021).

The Biology Interest Scale was developed based on literature and discussions with subject matter experts as well as students to determine factors and questions to gauge interest in biology.

The Biology Self-Efficacy Scale for Nonmajors is a 23-item scale developed to assist with testing the effectiveness of learning and teaching strategies that may increase biological literacy in nonmajors (Baldwin et al., 1999). Factor analysis and criterion validation were both conducted on the scale. Three factors were extracted, and reliability tests yielded Cronbach's alpha coefficients of 0.88, 0.88, and .89 for each factor respectively (Baldwin et al., 1999). Criterion validation for the scale resulted in low (0.18 to 0.27) Pearson *r* values showing that the scale differentiates self-efficacy from biology process and content subscales from the National Association of Biology Teachers Biology Examination (Baldwin et al., 1999). While the instrument is intended for nonmajors, it has been deemed suitable for use with freshman biology majors as they are unfamiliar with higher education level biology (Ainscough et al., 2016). Furthermore, Ainscough et al. (2016) argued that the scale is suitable for incoming biology majors as their study included a mixture of biology and chemistry majors and more than two thirds of the participants had science backgrounds; yet only 10 (1.6%) students scored a maximum score on any subscale and 38 (6.2%) students reached the ceiling of a subscale by the end of the semester. These results indicate the scale is suitable for freshman biology majors.

**Institutional Data**

Institutional data was collected from East Carolina University in Spring 2023 to track declared and/or intended major, STEM course grades from Fall 2022 and Spring 2023 enrollment for students participating in the Fall 2022 survey data collection. These data were used to verify retention of students in the major or university and determine whether students left due to low grades or if certain survey scores serve as indicators of a student at risk of leaving.

**Interviews**

On the post-survey, Fall 2022 students were asked if they were willing to be interviewed. Interviews were conducted online via Webex and students were asked to discuss topics such as their experience, feelings about the intervention, and biology as a major (Appendix G). The interviews were recorded and then coded for major themes by a colleague and I for analyses. Students completing an interview were given a $20 Amazon gift card.

**Data Analysis**

After data collection, I cleaned the survey data by removing data from individuals who did not complete both the pre and post surveys as well as any survey with less than 50% of the questions answered or any survey with a failed attention check question. After cleaning I was left with 139 individuals. Institutional data was requested for only those 139 individuals. Each of those respondents were asked if they would be willing to participate in an interview and 118 said they were. Of those, only three responded to a follow up inquiry and participated in their scheduled interview. Any information that could be used to identify a participant was removed from the survey and interview results, and each participant was assigned a random, unique number as an identifier. Only deidentified data was used for analyses. SPSS (IBM) was used for quantitative analysis while NVivo (QSR International) was used for qualitative analysis.

## Survey

Certain demographic responses had to be grouped together to have a large enough sample size to run analyses. The categories for race, age, and academic standing were collapsed into smaller numbers of groups (Table 2.1). Separate factorial ANOVAs were run for the response variable corresponding to each hypothesis: grit, retention, biology interest and biology self-efficacy. The independent variables included in all ANOVAs were group, pre/post, course, race, gender, age, academic standing, and interest in entrepreneurship (Table 2.1). The mean Likert scores for all items within a subscale (e.g., all items pertaining to grit) were calculated. For most questions in the survey, a higher Likert score meant a more strongly positive response (e.g., more interest) but the self-efficacy questions were written such that a lower score meant a more positive response (e.g., higher self-efficacy). To make all the response variables have a higher score equating to a more positive response, the self-efficacy questions were reverse coded. Therefore, a higher mean score for all response variables equates to a more positive response (e.g, more grit).

## Institutional Data

Data was gathered on the number of students from the study who failed a STEM course during the semester of the study, did not enroll the next semester, dropped the biology major or intended major after the semester of the study, or, for students enrolled in Biol 1101 during fall 2022, did not continue to the second course in the Introductory Biology sequence. I used t-tests to compare the survey scores of those students who failed, did not enroll, dropped the major, or did not continue the sequence to those who did not in order to determine if a specific score or factor was important for retaining students. Due to the small number of students who did not enroll the following semester (9) and the fact that no students changed their major away from biology, analysis was limited to students who failed courses. Two two-tailed T-tests were conducted, one on pre- and one on post-survey scores. to determine if any score differences exist between students who failed and students who passed. The null hypothesis was that students who failed a STEM course do not differ in their survey scores compared to students who did not fail a STEM course. The alternative hypothesis was that students who failed a STEM course differ in their survey scores compared to students who did not fail a STEM course.

*Table 2.1. Demographics of Sample Population*

| Variable | Options | Frequency |
|---|---|---|
| Age (Grouped) | 18 | 93 |
| | 19+ | 46 |
| Course | 1101 | 124 |
| | 1120 | 15 |
| Group | Treatment | 79 |
| | Comparison | 60 |
| Gender | Male | 43 |
| | Female | 95 |
| Race (Grouped) | White/Caucasian | 95 |
| | All Other | 44 |
| Academic Standing (Grouped) | Freshman | 97 |
| | All Other | 42 |
| Entrepreneurship Interest | Yes | 84 |
| | No | 55 |

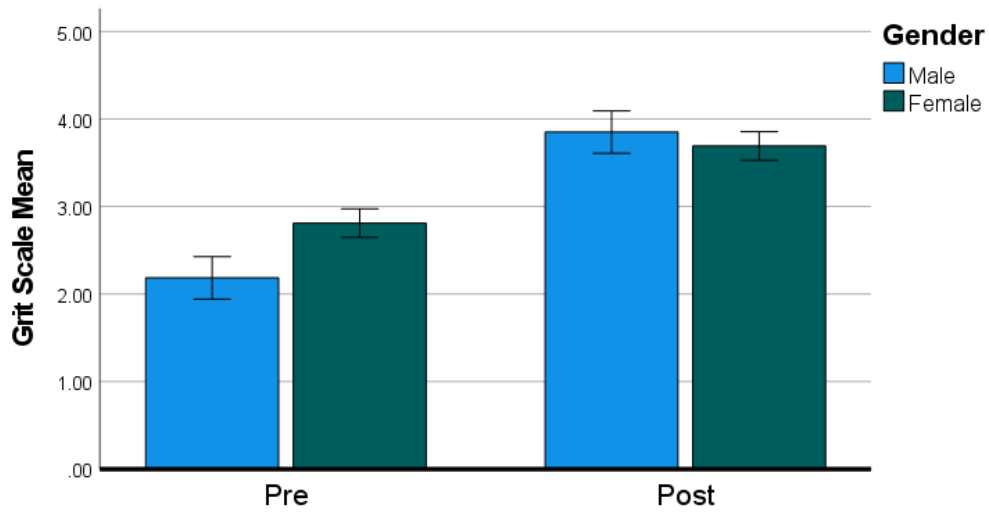
**Interviews**

A list of initial codes was generated for the analysis of the interviews using information from published literature and the research questions. Additional codes were added based on iteratively reviewing the responses. A peer and I coded the transcripts separately and then calculated interrater reliability (IRR) using Cohen's Kappa. A high interrater reliability indicates that the coding results can be replicated across individuals. Disagreements in coding were resolved through discussion before revising the codebook and recoding the transcripts to calculate a new kappa coefficient. This process was repeated until a high IRR was achieved (kappa = 0.8495). I recorded the number of codes and assigned them to a theme, and then calculated percent coverage for each code. Percent coverage was calculated as the proportion of characters from the entire interview transcript that the code represents. For example, if the transcript contains 100 characters and a code represents 10 of those characters, then the percent coverage for that code would be 10%.

## Chapter 3: Results

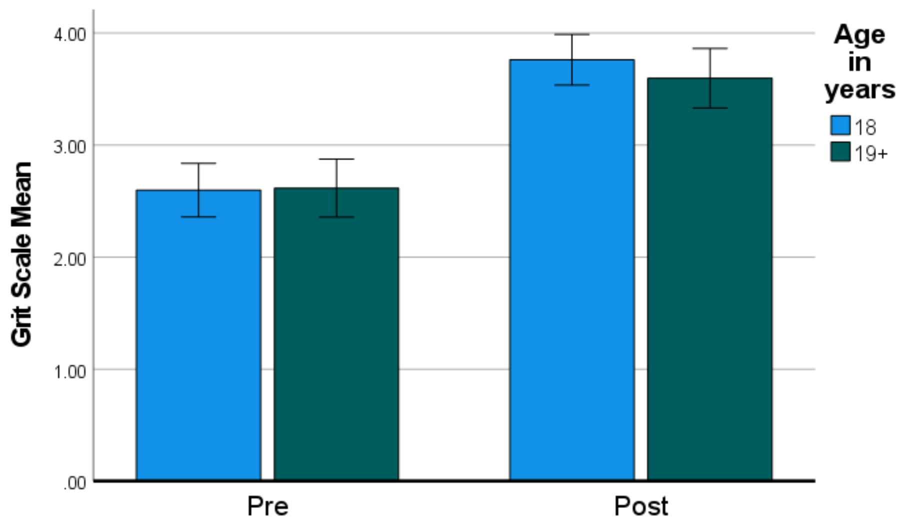
### Grit

The factorial ANOVA for grit was significant ($F_{1, 96} = 2.821$ $p < 0.001$; Table A1 and the independent variables accounted for approximately 39% of the variation (adjusted $R^2 = 0.387$). While there was no significant effect of group ($F_{1, 79} = 0.797$, $p = .373$) or interaction of group with pre/post ($F_{1, 79} = 0.297$, $p = .586$), there were some significant effects and interactions. Pre/post ($p < .001$) and course ($p < .001$) each had a significant main effect on grit scores. Grit scores increased over time (pre- to post-) for participants and students in 1101 reported higher grit than those in 1120. There was a statistically significant interaction between the effects of pre/post and gender ($F_{1, 79} = 4.593$, $p = .033$; Figure 3.1), pre/post and age ($F_{1, 79} = 4.673$, $p = .032$; Figure 3.2) as well as course and group (treatment or comparison; $F_{1, 79} = 5.923$, $p = .016$; Figure 3.3). Both genders experienced an increase in grit over time but although females started with significantly higher grit than males, that difference was no longer significant on the post-survey. Both age groups also experienced increased grit over time, but the 18-year-olds showed a larger increase in grit than those in the 19+ group. Finally, Biol 1101 students in the comparison group reported similar grit to 1101 students in the treatment group but in Biol 1120 the treatment group students reported higher grit than those in the comparison group. No other main effects or interactions were statistically significant for grit.




p < .001

*Figure 3.1. Interaction Effects of Gender and* Pre/Post *on Grit. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher mean values indicate higher grit.*




p = .032

*Figure 3.2. Interaction effects of Age and* Pre/Post *on Grit. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate higher grit.*

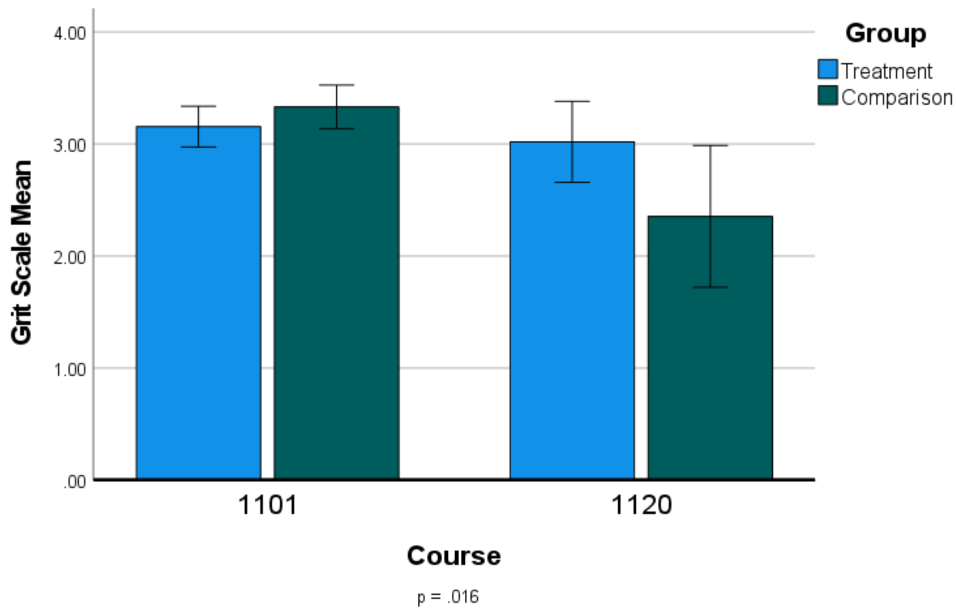



*Figure 3.3. Interaction effects of Course and Group on Grit. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate higher grit.*

**Retention**

The factorial ANOVA for retention was significant ($F_{1, 96} = 4.722$, $p < 0.001$; Table A2) and the independent variables accounted for approximately 56% of the variation (adjusted $R^2 = 0.563$). There again was no significant main effect of group ($F_{1, 79} = 1.410$, $p = .237$) or interaction of group with pre/post ($F_{1,79} = 1.125$, $p = .290$), but there was a significant main effect of pre/post ($F_{1,79} = 86.765$, $p < 0.001$) in which the students' intention to stay at the university was higher at the end of the semester than at the beginning. In addition, there was a significant main effect of course ($F_{1, 79} = 5.961$, $p = .018$) where students in 1101 expressed higher intention to stay at the university than those in 1120. There was also a significant interaction between group (treatment, comparison) and course on retention ($F_{1, 79} = 5.062$, $p = 0.026$; Figure 3.4). Students in the treatment group in Biol 1120 were more likely to say they would stay at the university than students in the comparison group in Biol 1120. In Biol 1101, however, students in the comparison group had similar plans to retain than the treatment group. No other main effects or interactions were statistically significant for retention.

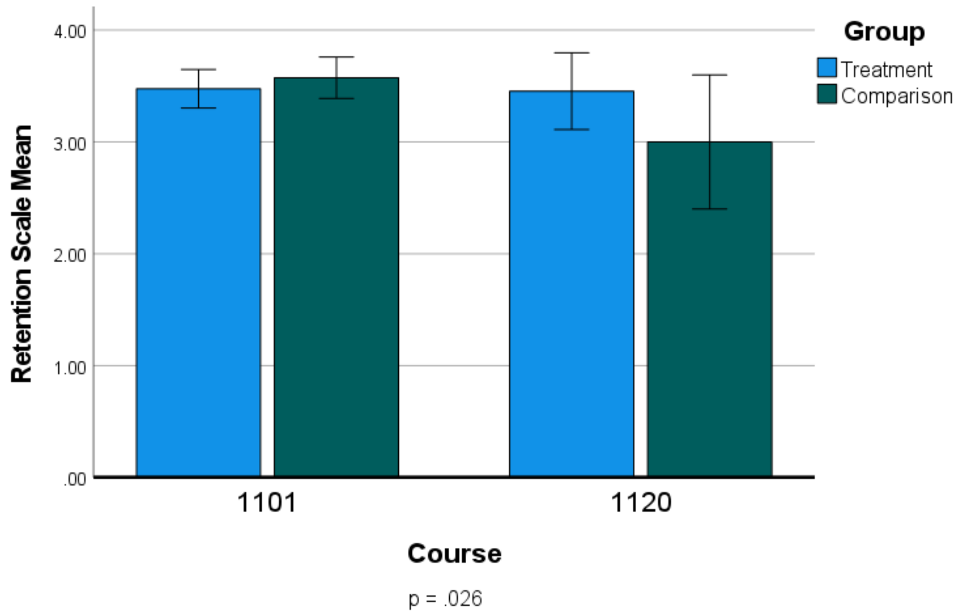



*Figure 3.4. Interaction Effects of Course and Group on Retention. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate greater intention to remain at the university.*

**Biology Interest**

The factorial ANOVA for biology interest was significant ($F_{1, 96} = 1.684$, p = 0.001; Table A3) and the independent variables accounted for approximately 19% of the variation (adjusted $R^2 = 0.192$). There was no significant effect of group ($F_{1, 79} = 1.380$, $p = .242$) or interaction of group with pre/post ($F_{1, 79} = 1.724$, $p = .191$). Course had a statistically significant main effect on biology interest scores ($F_{1, 79} = 7.860$, p = .006) with students in 1101 expressing more interest in biology than those in 1120. There was a statistically significant interaction between the effects of pre/post and interest in entrepreneurship ($F_{1, 79} = 6.204$, $p = .014$; Figure 3.5), in which the pre-survey students who were not interested in entrepreneurship showed greater biology interest than those with an interest in entrepreneurship, but on the post-survey students with an interest in entrepreneurship had higher biology interest than those who were not interested in entrepreneurship. Those with an interest in entrepreneurship gained interest in biology over the semester while the students without an interest in entrepreneurship lost interest in biology. There was also a statistically significant interaction between pre/post and course ($F_{1, 79} = 12.467$, $p < .001$; Figure 3.6), in which students in 1101 started off with higher biology interest than those in 1120 but lost interest over time whereas students in 1120 gained interest in biology over time, ending the semester with a similar interest level to the 1101 students from the beginning of the semester. In addition, there was a significant interaction between race and group ($F_{1, 79} = 4.268$, $p = .040$; Figure 3.7), in which white students in the comparison group expressed more interest in biology than whites in the treatment group and all other races in the comparison group. The treatment group of all other races had higher biology interest than the comparison group of all other races and higher biology interest than whites in the treatment group. Finally, there was also a significant interaction between course and group ($F_{1, 79} = 8.744$, $p = .004$; Figure 3.8). Students in 1101 in the comparison group had slightly higher biology interest than those in the treatment group, however, the opposite was true of 1120 in which the treatment group expressed slightly higher biology interest than the comparison group. No other main effects or interactions were statistically significant for biology interest.

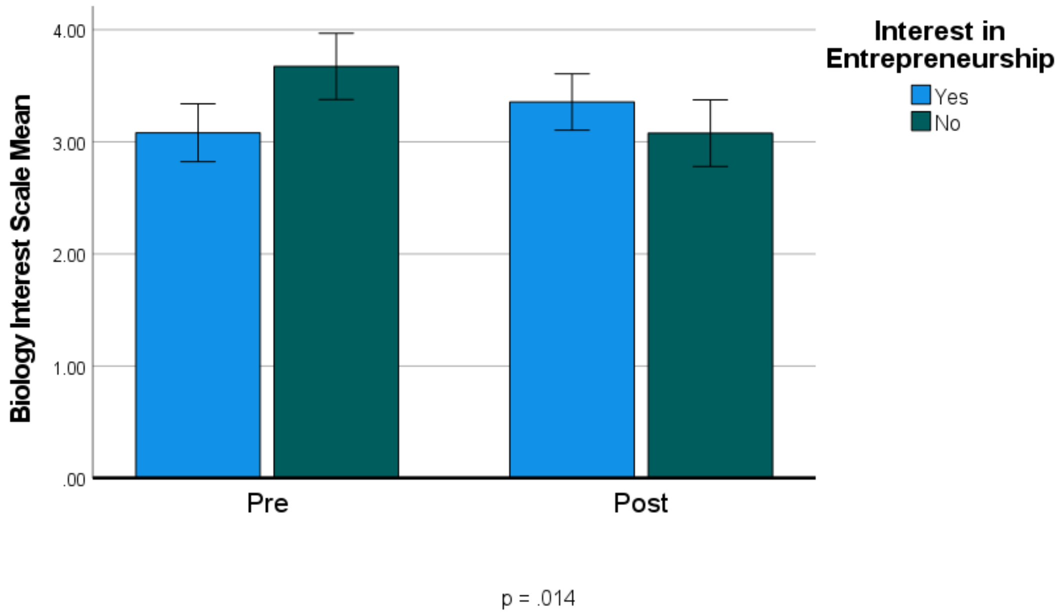



*Figure 3.5. Interaction Effects of Interest in Entrepreneurship and* Pre/Post *on Biology Interest. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher mean scores indicate greater levels of biology interest.*

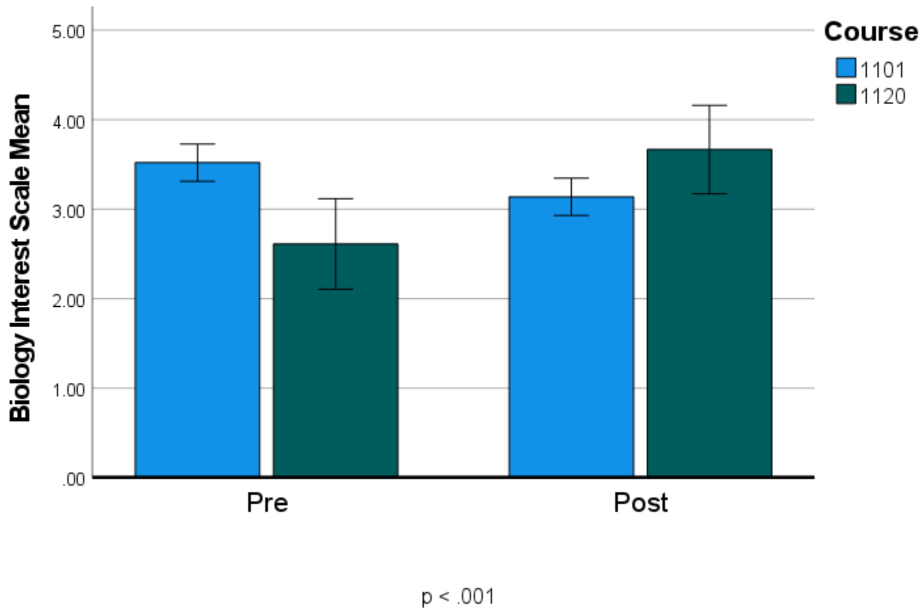



*Figure 3.6. Interaction Effects of Course and* Pre/Post *on Biology Interest. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate greater levels of biology interest.*

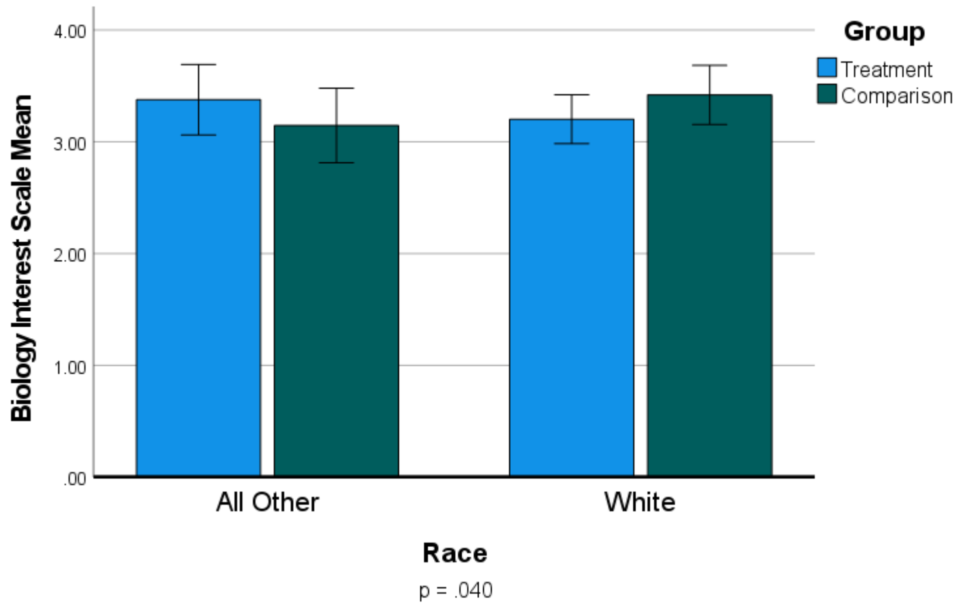



*Figure 3.7. Interaction Effects of Race and Group on Biology Interest. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate greater levels of biology interest.*

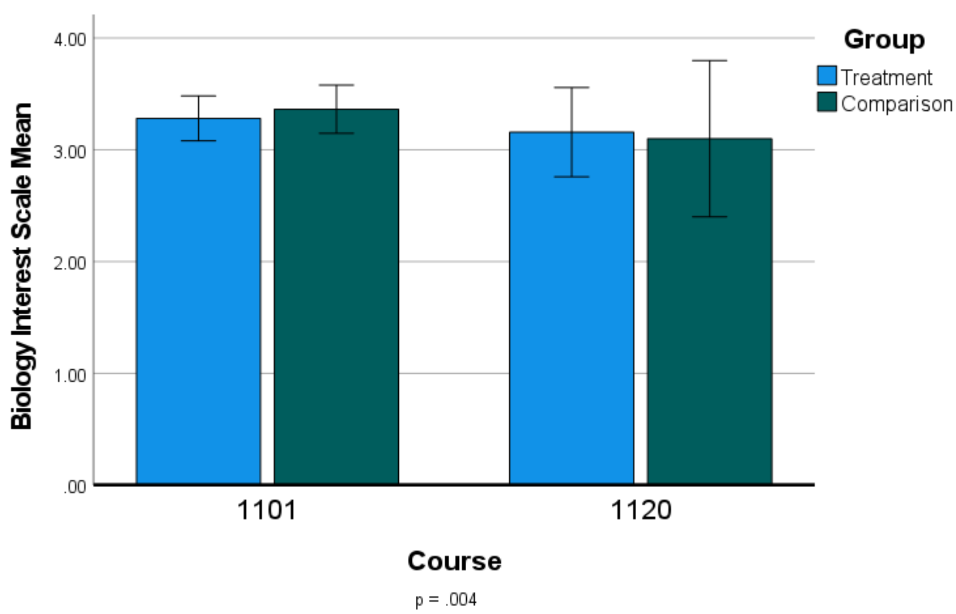


*Figure 3.8. Interaction Effects of Course and Group on Biology Interest. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate greater levels of biology interest.*

**Biology Self-Efficacy**

The factorial ANOVA for biology self-efficacy was not significant ($F_{1, 96}$ = 1.254, p < 0.098; Table A4), in which the independent variables accounted for approximately 8% of the variation (adjusted $R^2$ = 0.081). There was no significant effect of group ($F_{1, 79}$ = 0.721, *p* = .397) or interaction of group with pre/post ($F_{1, 79}$ = 0.274, *p* = .602), but there were three significant main effects and one significant interaction. Interest in entrepreneurship ($F_{1, 79}$ = 4.189, *p* = .042), course ($F_{1, 79}$ = 8.428, *p* = .004), and academic standing ($F_{1, 79}$ = 5.682, *p* = .018) all had statistically significant main effects on biology self-efficacy scores. Students interested in entrepreneurship expressed lower biology self-efficacy than students who were not interested in entrepreneurship. Students in 1120 expressed lower self-efficacy than those in 1101, and freshman expressed higher biology self-efficacy than all other academic standings. There was a statistically significant interaction between the effects of group and course ($F_{1, 79}$ = 5.217, *p* = .024; Figure 3.9). Treatment group students in 1120 reported higher biology self-efficacy than those in the comparison group while in 1101 the comparison group expressed slightly higher biology self-efficacy than those in the treatment group. No other main effects or interactions were statistically significant for biology self-efficacy.

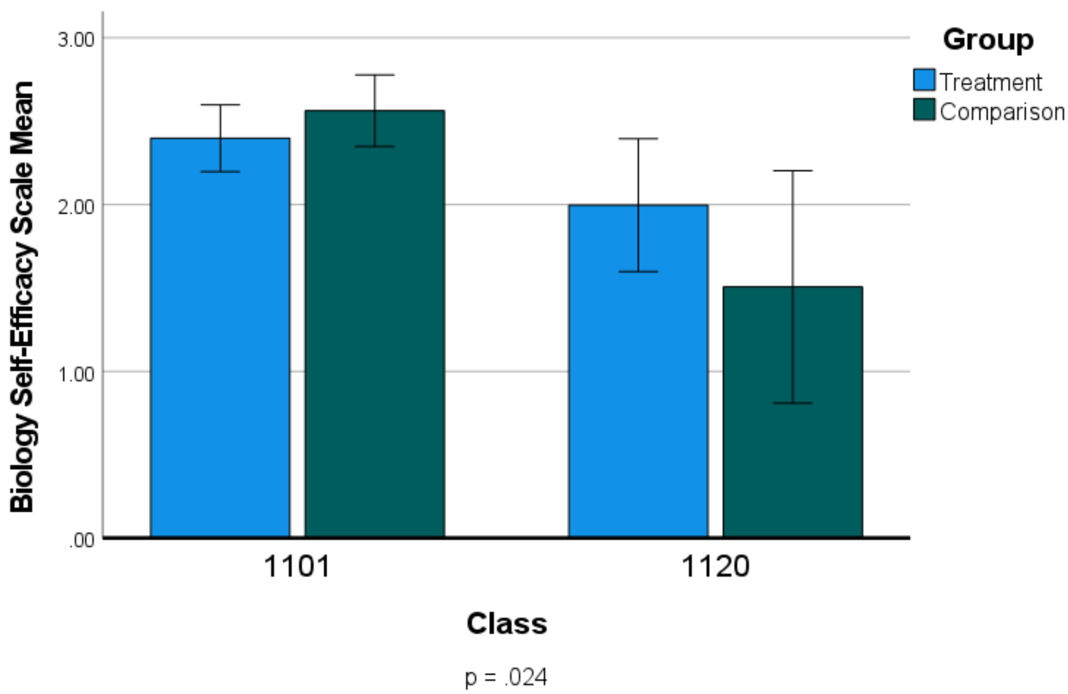



*Figure 3.9. Interaction effects of Course and Group on Biology Self-Efficacy. Error bar represents means +/- 95% CI. P value represents the interaction effect. Higher means indicate greater levels of biology self-efficacy.*

**Institutional Data**

A two-tailed independent samples t-test was conducted to determine if there is a relationship between scale scores on the pre-survey or post-survey for those who failed a STEM course and those who did not. Pre- scores for biology self-efficacy ($t(137) = 1.881$, $p = .018$) and retention ($t(66.832) = 2.019$, $p = .047$) were significantly lower for those who failed a course than those who did not fail. Pre-scores for biology interest ($p = .427$) and grit ($p = .673$) were not significantly different between those who failed a course and those who did not. On the post-survey scores, only biology self-efficacy was significantly different between those who failed a course and those who did not ($t(81.101) = 2.172$, $p = .033$). Post-scores for biology interest ($p =$

.865), retention ($p$ = .254), and grit ($p$ = .559) did not differ between those who failed a course and those who did not.

**Interviews**

The final interview codebook had 12 codes which I consolidated into six themes and report percent coverage (Table 3.6). An interesting phenomenon found in the codes is that every participant expressed an interest in helping the world whether it be humans, animals, or the environment, but none of the participants expressed an interest in entrepreneurship. When asked, students overwhelmingly preferred to be exposed to entrepreneurship earlier in their academic career (freshman or sophomore) as opposed to later (junior or senior) as no codes for later were ever found. Two out of the three students expressed that their course and or the modules exposed them to a variety of available careers available, however, one student said they felt they were not exposed to a variety of careers. Job satisfaction was important for students when choosing their major and deciding on a career within their major, as students expressed work-life balance or being happy within the job in every code for that theme. Another negative sentiment expressed by students was that one student said they did not feel equipped with the lab skills to succeed in a biology career while one student expressed that they felt equipped and another said that since they are a freshman, they have limited skills due to limited college experience.

*Table 3.6. Final Themes, Codes and Percent Coverage*

| Theme | Node | References | % Coverage |
|---|---|---|---|
| Deciding a Major | Helping the World | 8 | 6.58% |
| Entrepreneurship Introduction | Early (freshman/sophomore) | 8 | 7.31% |
| | Later (junior/senior) | 0 | 0% |
| Career Variety | Exposure to Variety | 8 | 4.09% |
| | No Exposure to Variety | 2 | 6.11% |
| Career Potential | Job Satisfaction | 6 | 5.59% |
| | Career Availability | 4 | 3.66% |
| | Already Decided Career | 2 | 1.17% |
| Entrepreneurship Skills | Equipped from courses | 5 | 5.77% |
| | Limited skills as freshman | 3 | 9.76% |
| | Equipped from modules | 2 | 2.90% |
| | No skills | 2 | 4.59% |
| Entrepreneurship Interest | Important but Not Interested | 4 | 4.12% |
| | Not Interested | 4 | 1.89% |

# Chapter 4: Discussion

## Effects of Innovation Modules

These low-time commitment, online innovation modules did not significantly impact biology interest, grit, self-efficacy, or plans to stay at the university. However, the treatment had some more subtle interactive effects with respect to course and race. Students responded differently to the treatments for all response variables based on the course they were in (1101, 1120). In addition, non-white students had slightly different responses to the treatments in respect to biology interest than white students.

The students in Biol 1120 who experienced the innovation modules had higher grit, biology self-efficacy, retention plans, and (slightly) biology interest than those who completed the comparison modules. These differences were much smaller or non-existent with Biol 1101 students, who included a much greater percentage of students planning to apply to medical, dental, or PA school after graduation. Students who think they are going to professional school may be more confident in themselves and sure about their career path and are likely not as interested in entrepreneurship or other careers. Whereas students taking a Careers in Biology course may be more unsure of their abilities and career opportunities, resulting in lower scores for these response variables. Future research is required to test these hypotheses and determine if additional supports like the innovation modules are useful for students not seeking professional school as it helps them see the relevance of their major outside of subsequent degrees.

Future research should examine whether STEM students uncertain of their career path have experienced prior failure to a different degree or with a different outcome than students intending to apply to professional school. Students in the treatment group of 1120 may have expressed higher grit than those in the comparison group because their previous failures or experiences with adversity were validated by the treatment's modules depicting failure and adversity as common and expected in the sciences. This acceptance of failure, coupled with information on how to leverage their knowledge to solve real world problems as a scientist, may also explain why the 1120 students expressed higher biology self-efficacy and biology interest than the comparison group. Explicitly discussing these ideas in the treatment modules may have increased student's self-efficacy by reducing the doubt about their ability to do biology that was caused by a prior failure.

In addition, further research is required to determine if innovation modules can increase interest in STEM students uncertain of their career path by showing potential applications of science. I hypothesized there would be positive impacts in the treatment group, and it appears to be supported 1120 but not 1101 (where many students intend to apply to professional school). Prior subject knowledge and ability has been shown to positively impact self-efficacy (Ineson et al., 2012) and the more knowledge or expertise one has, the more accurately they can estimate their abilities (Ferarro 2010; Kruger and Dunning 1999; Schlösser et al, 2013). Since the majority of the students in 1101 intend to apply to professional schools, they may have more prior subject knowledge or extracurricular experiences than students in 1120. Future research should examine whether prior experiences and knowledge differ between these two biology student populations and whether than results in STEM students who intend to apply to professional schools expressing higher biology self-efficacy.

The data also suggests that non-white students completing the treatment modules may have had slightly higher biology interest compared to non-white students completing the comparison modules. Showing underrepresented students how to use their knowledge and help their community has been shown previously to increase interest and retention in sciences

(Estrada et al., 2017; Jordt et al., 2017). Therefore, future research could examine whether providing innovation education for underrepresented science students increases participation and retention of these students.

**Other Effects**

This study reveals a loss in biology interest over time for students. However, students with an interest in entrepreneurship (regardless of module group) had higher biology interest. As there was no significant improvement of biology interest from pre- to post- survey in the treatment group, more research is needed in how to leverage this connection between interest in entrepreneurship and biology interest. Students in 1120 expressed low biology interest on the pre-survey but gain interest over time, even surpassing the biology interest of students in 1101 on post-survey. The goal of Biol 1120 is to show students different career opportunities in biology as well as how to leverage their knowledge. This exposure to a broader view of biology may be fostering more interest in biology but further research is necessary to confirm this hypothesis.

Grit and intention to stay at the university increased in the students over time as they became familiar with the campus, university level coursework, and studying independently. As students experienced success and persevered through difficult coursework, they increased their grit. Developing coursework and the first-year experience for students around fostering this increase in grit may help students persevere throughout all hardships in their life, not just academia. Deliberately fostering this building of grit and retention in students during the first semester at university may increase the gain in these factors of students and deliver better results. The students are experiencing college level courses and independence for the first time and designing courses to aid students in building their grit and retention scores may lead to increased retention rates of students down the line (Bashant 2014; Hodge, Wright & Bennett 2017).

Time had significant interactive effects with gender and with age on grit. Women entered the semester with higher grit than men, possibly due to the fact that women tend to endure more hardship than men and generate more grit before entering university (Bashant 2014; Hodge, Wright & Bennett 2017). Conversely, both age groups expressed similar grit on the pre-survey and increased their grit over time, but 18-year-olds ended with more grit than 19+ group.

Biology self-efficacy was significantly impacted by a student's interest in entrepreneurship and academic standing (year in school). Students interested in entrepreneurship expressed lower biology self-efficacy, possibly because they know what they do not know and are aware of high-level research or medical skills they do not have yet. Students not interested in entrepreneurship may not be thinking about solving real world problems with their knowledge and therefore are more confident in their biological skills based on academic course work alone. This same phenomenon of knowing what you do not know may also be responsible for freshman showing higher levels of biology self-efficacy than the other levels (sophomore, junior, and senior).

Finally, students who ultimately failed a STEM course had reported significantly lower biology self-efficacy and planned retention scores on the pre-survey than those who did not fail. The difference in retention scores disappeared on the post-survey so students who failed a STEM course did not appear to be discouraged from staying at university. These students still reported significantly lower biology self-efficacy scores at the end of the semester. Future research could determine whether administering self-efficacy and planned retention surveys at the beginning of a semester allows researchers to identify students who are at greater risk of failing and target extra support to these students.

While the intervention itself did not produce improvements in grit, retention, self-efficacy, or interest, further research may be warranted on the impacts of entrepreneurship education (with a different duration, format, or curriculum) on biology students. Based on the qualitative data, every student expressed that showing different career options made them more likely to stay in or choose biology as a major. Every student also indicated that scientific entrepreneurship should be introduced to students early in their academic career as opposed to later as they thought they could apply these lessons to their higher-level courses better if they learned it earlier. All three students also said that they were interested in or chose biology because the major can help improve the planet for all its inhabitants and highlighting scientific entrepreneurs and their innovations can help foster that interest.

**Limitations**

A significant limitation of this study is the duration of the intervention and data collection. The modest time commitment required for this intervention by students, however, was by design to determine if an effect could be detected. This type of online, outside-of-class, intervention would be much easier to integrate widely into science programs than a more time intensive intervention. Unfortunately, this type of intervention did not have a detectable effect on this study population. In addition, the students were only tested over the span of a month and institutional data collected for two consecutive semesters. There was no attrition from the major over the two semesters of data collection and the data collection for the second semester occurred after the semester started but students could have changed their major or dropped the Introductory Biology II course later. This study also occurred during the first semester for most students. The first semester of university includes many new experiences, and this study could not account for these other impacts.

Another limitation of this study is the sample size. Due to the large number of students who failed the attention check questions, the usable sample size fell below our expectations. To have a large enough sample size for certain groups, I had to lump specific demographic categories together (e.g., racial groups). This aggregation limits the study's ability to determine the impact on specific demographic groups. This limitation may be particularly relevant to our grouping of race as the non-white grouping including all other racial groups, including those of Asian descent, who are not generally considered a minority in STEM fields. The response rate between the two courses, 1101 and 1120, is also vastly different with 1101 representing over 85% of the sample.

Furthermore, interview participation is also limitation of this study. Only three participants attended their scheduled interview and one of them was part of the comparison group. While this small data sample still provides insight into the data and design of future interventions, it is not large enough to provide more generalizable conclusions.

## References


Ainscough, L., Foulis, E., Colthorpe, K., Zimbardi, K., Robertson-Dean, M., Chunduri, P., & Lluka, L. (2017). Changes in Biology Self-Efficacy during a First-Year University Course. *Https://Doi.Org/10.1187/Cbe.15-04-0092*, *15*(2). https://doi.org/10.1187/CBE.15-04-0092

American Association for the Advancement of Science & National Science Foundation. (2011). *Vision and Change in Undergraduate Biology Education A Call to Action.* https://visionandchange.org/wp-content/uploads/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Baldwin, J. A., Ebert-May, D., & Burns, D. J. (1999). The Development of a College Biology Self-Efficacy Instrument for Nonmajors. *Science Education*, *83*(4), 397–408. https://doi.org/10.1002/(SICI)1098-237X(199907)83:4%3C397::AID-SCE1%3E3.0.CO;2-%23

Bashant, J. (2014). Developing Grit in Our Students: Why Grit Is Such a Desirable Trait, and Practical Strategies for Teachers and Schools. *Journal for Leadership and Instruction*, *13*, 14–17.

Bandura, A. 1986. Social Foundations of Thought and Action: A Social Cognitive Theory. Englewood Cliffs, NJ: Prentice-Hall.

Bilén, S. G., Kisenwether, E. C., Rzasa, S. E., & Wise, J. C. (2005). Developing and Assessing Students' Entrepreneurial Skills and Mind-Set. *Journal of Engineering Education*, *94*(2), 233.

Brown, J. T., & Kant, A. C. (2008). Creating bioentrepreneurs: How graduate student organisations foster science entrepreneurship. *Journal of Commercial Biotechnology 2008 15:2*, *15*(2), 125–135. https://doi.org/10.1057/JCB.2008.41

Chaney, B. H., Christensen, T. W., Crawford, A., Ford, K., Fraley, T., Godwin, W. W., & Weckesser, G. (2021). Building entrepreneurial self-efficacy through honors education. In *Journal of Entrepreneurship Education* (Vol. 24, Issue 3).

Chaney, B. H., Christensen, T. W., Crawford, A., Ford, K., & Godwin, W. W. (2020). *Best Practices in Honors Pedagogy: Teaching Innovation and Best Practices in Honors Pedagogy: Teaching Innovation and Community Engagement through Design Thinking Community Engagement through Design Thinking*. https://digitalcommons.unl.edu/nchchip

*Connect Network*. CONNECT Network. (n.d.). https://ubeconnected.org/

Crispeels, T., Uecke, O., Goldchstein, M., & Schefczyk, M. (2008). Best practices for developing university bioentrepreneurship education programmes. *Journal of Commercial Biotechnology 2008 15:2*, *15*(2), 136–150. https://doi.org/10.1057/JCB.2008.44

Davidson, W. B., & Beck, H. P. (2021). A Two-Minute Test to Identify Undergraduates Likely to Drop Out. *College Student Journal*, *55*(1), 56–66.

Doorley, S. D., Holcomb, S. H., Klebahn, P. K., Segovia, K. S., & Utley, J. U. (2018). *Design Thinking Bootleg* [Slides]. Stanford D.School. https://static1.squarespace.com/static/57c6b79629687fde090a0fdd/t/5b19b2f2aa4a99e99b26b6bb/1528410876119/dschool_bootleg_deck_2018_final_sm+%282%29.pdf

Duckworth, A. L., & Quinn, P. D. (2009). Development and validation of the short grit scale (grit–S). *Journal of Personality Assessment*, *91*(2), 166–174. https://doi.org/10.1080/00223890802634290

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., Hurtado, S., John, G. H., Matsui, J., McGee, R., Okpodu, C. M., Robinson, T. J., Summers, M. F., Werner-Washburne, M., & Zavala, M. (2017). Improving underrepresented minority student persistence in STEM. *CBE—Life Sciences Education*, *15*(3). https://doi.org/10.1187/cbe.16-01-0038

Ferraro, P. J. (2010). Know thyself: Competence and self-awareness. *Atlantic Economic Journal*, *38*(2), 183–196. https://doi.org/10.1007/s11293-010-9226-2

Garriott, P. O., Navarro, R. L., & Flores, L. Y. (2017). First-Generation College Students' Persistence Intentions in Engineering Majors. *Journal of Career Assessment, 25(1),* 93–106. https://doi.org/10.1177/1069072716657533

Gore, P. A., & Leuwerke, W. C. (2000). Predicting Occupational Considerations: A Comparison of Self-Efficacy Beliefs, Outcome Expectations, and Person-Environment Congruence. *Journal of Career Assessment*, *8*(3), 237–250. https://doi.org/10.1177/106907270000800303

Hodge, B., Wright, B. & Bennett, P. The Role of Grit in Determining Engagement and Academic Outcomes for University Students. Res High Educ59, 448–460 (2018). https://doi.org/10.1007/s11162-017-9474-y

Ineson, E. M., Jung, T., Hains, C., & Kim, M. (2013). The influence of prior subject knowledge, prior ability and work experience on self-efficacy. *Journal of Hospitality, Leisure, Sport & Tourism Education*, *12*(1), 59–69. https://doi.org/10.1016/j.jhlste.2012.11.002

Jordt, H., Eddy, S. L., Brazil, R., Lau, I., Mann, C., Brownell, S. E., King, K., & Freeman, S. (2017). Values affirmation intervention reduces achievement gap between underrepresented minority and white students in introductory biology classes. *CBE—Life Sciences Education*, *16*(3). https://doi.org/10.1187/cbe.16-12-0351

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, *77*(6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*, 79–122. doi:10.1006/jvbe.1994.1027

Lent, R. W., Brown, S. D., & Hackett, G. H. (2002). Career Choice and Development (D. Brown, Ed.; 4th ed.. 255-311). Wiley.

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology, 50,* 458–465. doi:10.1037/0022-0167.50.4.458

Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at Historically Black Universities. *Journal of Counseling Psychology, 52*, 84–92. doi:10.1037/0022-0167.52.1.84

Lent, R. W., Lopez, A. M., Lopez, F. G., & Sheu, H. Bin. (2008). Social cognitive career theory and the prediction of interests and choice goals in the computing disciplines. *Journal of Vocational Behavior*, *73*(1), 52–62. https://doi.org/10.1016/J.JVB.2008.01.002

Meyers, A. (2014). Bioentrepreneurship Education and Training Trends. *Journal of Commercial Biotechnology*, *20*(2), 62–63. https://doi.org/10.5912/JCB647

National Research Council 2015. Enhancing the Effectiveness of Team Science. Washington, DC: The National Academies Press. https://doi.org/10.17226/19007.

Neergaard, H., Robinson, S., & Jones, S. (2020). Transformative learning in the entrepreneurship education process: the role of pedagogical nudging and reflection. *International Journal of Entrepreneurial Behavior & Research, 27(1),* 251–277. https://doi.org/10.1108/IJEBR-04-2020-0235

Newman, A., Obschonka, M., Schwarz, S., Cohen, M., & Nielsen, I. (2019). Entrepreneurial self-efficacy: A systematic review of the literature on its theoretical foundations, measurement, antecedents, and outcomes, and an agenda for future research. *Journal of Vocational Behavior*, *110*, 403–419. https://doi.org/10.1016/J.JVB.2018.05.012

Ohland, M. W., Frillman, S. A., Zhang, G., Brawner, C. E., & Miller, T. K. (2013). The Effect of an Entrepreneurship Program on GPA and Retention*. *Journal of Engineering Education*, *93*(4), 293–301. https://doi.org/10.1002/j.2168-9830.2004.tb00818.x

Pittaway, L., & Cope, J. (2007). Entrepreneurship education: A systematic review of the evidence. *International Small Business Journal*, *25*(5), 479–510. https://doi.org/10.1177/0266242607080656

Rideout, E. C., & Gray, D. O. (2013). Does Entrepreneurship Education Really Work? A Review and Methodological Critique of the Empirical Literature on the Effects of University-Based Entrepreneurship Education. *Journal of Small Business Management*, *51*(3), 329–351. https://doi.org/10.1111/JSBM.12021

Rocha, L., & Lenz, A. S. (2022). Psychometric meta-analysis of the short grit scale reliability across demographic groups and academic settings. *Counseling Outcome Research and Evaluation*, 1–14. https://doi.org/10.1080/21501378.2022.2065975

Rzasa, S. E., Wise, J. C., & Kisenwether, E. C. (2004). *Evaluation of Entrepreneurial Endeavors in the Classroom: The Student Perspective*. National Collegiate Inventors & Innovators Alliance.

Schlösser, T., Dunning, D., Johnson, K. L., & Kruger, J. (2013). How unaware are the unskilled? empirical tests of the "signal extraction" counterexplanation for the dunning–kruger effect in self-evaluation of performance. *Journal of Economic Psychology*, *39*, 85–100. https://doi.org/10.1016/j.joep.2013.07.004

U.S. Census Bureau. (2014, July 10). *Where do college graduates work?* United States Census Bureau. Retrieved October 9, 2021, from https://www.census.gov/dataviz/visualizations/stem/stem-html/

## Appendix A: Institutional Review Board Pre-Research Approval

**EAST CAROLINA UNIVERSITY**
**University & Medical Center Institutional Review Board**
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

### Notification of Exempt Certification

From: Social/Behavioral IRB
To: Heather Vance Chalcraft
CC:
Date: 5/16/2022
Re: UMCIRB 22-000708
Does Entrepreneurship Education Impact Undergraduate Interest and Retention in Biology?

I am pleased to inform you that your research submission has been certified as exempt on 5/16/2022. This study is eligible for Exempt Certification under category # 1 & 2b.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.

This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.

| Document | Description |
|---|---|
| Consent Form(0.03) | Consent Forms |
| Focus Group Script(0.01) | Interview/Focus Group Scripts/Questions |
| Initial Recruitment Email Text(0.03) | Recruitment Documents/Scripts |
| Interview Recruitment Email Text(0.02) | Recruitment Documents/Scripts |
| Post Survey(0.03) | Surveys and Questionnaires |
| Pre Survey(0.03) | Surveys and Questionnaires |
| Weinthal Thesis Proposal(0.01) | Study Protocol or Grant Application |

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

## Appendix B: ANOVA Table for Grit

*Table A1. ANOVA Results for Grit. Significant factors noted by bold font.*

| | df | Mean Square | F | Significance |
|---|---|---|---|---|
| Interest in Entrepreneurship | 1 | $5.169 \times 10^{-5}$ | 0 | .993 |
| Academic Standing | 1 | .323 | .523 | .471 |
| Race | 1 | .088 | .142 | .707 |
| Age | 1 | .001 | .002 | .969 |
| **Pre/Post** | **1** | **29.893** | **48.424** | **< .001** |
| Group | 1 | .492 | .797 | .373 |
| **Course** | **1** | **7.956** | **12.888** | **< .001** |
| Gender | 2 | 1.566 | 2.536 | .082 |
| Interest in Entrepreneurship*Academic Standing | 1 | .944 | 1.529 | .218 |
| Interest in Entrepreneurship*Race | 1 | .007 | .012 | .913 |
| Interest in Entrepreneurship*Age | 1 | .238 | .385 | .536 |
| Interest in Entrepreneurship*Pre/Post | 1 | .028 | .045 | .832 |
| Interest in Entrepreneurship*Group | 1 | 1.382 | 2.239 | .136 |

| | | | | |
|---|---|---|---|---|
| Interest in Entrepreneurship*Course | 1 | .320 | .518 | .472 |
| Interest in Entrepreneurship*Gender | 1 | .010 | .017 | .897 |
| Academic Standing*Race | 1 | .880 | 1.426 | .234 |
| Academic Standing*Age | 1 | 1.521 | 2.464 | .118 |
| Academic Standing*Pre/Post | 1 | 1.252 | 2.028 | .156 |
| Academic Standing*Group | 1 | .081 | .132 | .717 |
| Academic Standing*Course | 0 | 0 | 0 | 0 |
| Academic Standing*Gender | 1 | .562 | .910 | .341 |
| Race*Age | 1 | .002 | .004 | .951 |
| Race*Pre/Post | 1 | .100 | .162 | .688 |
| Race*Group | 1 | .128 | .207 | .649 |
| Race*Course | 1 | .003 | .004 | .949 |
| Race*Gender | 1 | .221 | .358 | .550 |
| **Age*Pre/Post** | **1** | **2.885** | **4.673** | **.032** |
| Age*Group | 1 | .089 | .144 | .705 |
| Age*Course | 0 | 0 | 0 | 0 |
| Age*Gender | 1 | 0 | 0 | .983 |
| Pre/Post*Group | 1 | .183 | .297 | .586 |
| Pre/Post*Course | 1 | 1.894 | 3.068 | .082 |
| **Pre/Post*Gender** | **1** | **9.070** | **13.912** | **< .001** |

| | | | | |
|---|---|---|---|---|
| **Group*Course** | **1** | **3.657** | **5.923** | **.016** |
| Group*Gender | 1 | .030 | .049 | .824 |
| Course*Gender | 1 | .089 | .145 | .704 |

## Appendix C: ANOVA Table for Retention

*Table A2. ANOVA Results for Retention. Significant factors noted by bold font.*

| | df | Mean Square | F | Significance |
|---|---|---|---|---|
| Interest in Entrepreneurship | 1 | .805 | 1.454 | .229 |
| Academic Standing | 1 | .921 | 1.663 | .199 |
| Race | 1 | 1.433 | 2.588 | .109 |
| Age | 1 | .455 | .821 | .366 |
| **Pre/Post** | **1** | **48.053** | **86.765** | **< .001** |
| Group | 1 | .781 | 1.410 | .237 |
| **Course** | **1** | **3.152** | **5.961** | **.018** |
| Gender | 2 | 1.230 | 2.222 | .111 |
| Interest in Entrepreneurship*Academic Standing | 1 | .093 | .168 | .682 |
| Interest in Entrepreneurship*Race | 1 | .757 | 1.366 | .244 |
| Interest in Entrepreneurship*Age | 1 | 1.163 | 2.100 | .149 |
| Interest in Entrepreneurship*Pre/Post | 1 | 1.346 | 2.430 | .121 |
| Interest in Entrepreneurship*Group | 1 | .688 | 1.243 | .266 |

| | | | | |
|---|---|---|---|---|
| Interest in Entrepreneurship*Course | 1 | .231 | .417 | .519 |
| Interest in Entrepreneurship*Gender | 1 | .653 | 1.179 | .279 |
| Academic Standing*Race | 1 | .294 | .531 | .467 |
| Academic Standing*Age | 1 | .012 | .021 | .884 |
| Academic Standing*Pre/Post | 1 | .488 | .880 | .349 |
| Academic Standing*Group | 1 | .062 | .112 | .738 |
| Academic Standing*Course | 0 | 0 | 0 | 0 |
| Academic Standing*Gender | 1 | .116 | .210 | .647 |
| Race*Age | 1 | $1.021 \times 10^{-5}$ | 0 | .997 |
| Race*Pre/Post | 1 | .330 | .596 | .441 |
| Race*Group | 1 | .463 | .836 | .362 |
| Race*Course | 1 | 1.005 | 1.815 | .180 |
| Race*Gender | 1 | .121 | .218 | .641 |
| Age*Pre/Post | 1 | .002 | .004 | .948 |
| Age*Group | 1 | .206 | .372 | .543 |
| Age*Course | 0 | 0 | 0 | 0 |
| Age*Gender | 1 | 1.072 | 1.935 | .166 |
| Pre/Post*Group | 1 | .623 | 1.125 | .290 |
| Pre/Post*Course | 1 | .770 | 1.391 | .240 |
| Pre/Post*Gender | 1 | .295 | .532 | .467 |

| | | | | |
|---|---|---|---|---|
| **Group*Course** | **1** | **2.804** | **5.062** | **.026** |
| Group*Gender | 1 | .005 | .008 | .927 |
| Course*Gender | 1 | .179 | .324 | .570 |

## Appendix D: ANOVA Table for Biology Interest

*Table A3. ANOVA Results for Biology Interest. Significant factors noted by bold font.*

| | df | Mean Square | F | Significance |
|---|---|---|---|---|
| Interest in Entrepreneurship | 1 | .757 | 1.006 | .317 |
| Academic Standing | 1 | .136 | .180 | .672 |
| Race | 1 | 1.199 | 1.592 | .209 |
| Age | 1 | .752 | .999 | .319 |
| Pre/Post | 1 | .393 | .523 | .471 |
| Group | 1 | 1.039 | 1.380 | .242 |
| **Course** | **1** | **5.918** | **7.860** | **.006** |
| Gender | 2 | 1.655 | 2.198 | .114 |
| Interest in Entrepreneurship*Academic Standing | 1 | .519 | .690 | .407 |
| Interest in Entrepreneurship*Race | 1 | .161 | .214 | .644 |
| Interest in Entrepreneurship*Age | 1 | .165 | .219 | .640 |
| **Interest in Entrepreneurship*Pre/Post** | **1** | **4.671** | **6.204** | **.014** |
| Interest in Entrepreneurship*Group | 1 | 1.786 | 2.372 | .125 |

| | | | | |
|---|---|---|---|---|
| Interest in Entrepreneurship*Course | 1 | .024 | .032 | .858 |
| Interest in Entrepreneurship*Gender | 1 | .004 | .005 | .942 |
| Academic Standing*Race | 1 | .272 | .361 | .549 |
| Academic Standing*Age | 1 | .295 | .392 | .532 |
| Academic Standing*Pre/Post | 0 | .269 | .357 | .551 |
| Academic Standing*Group | 1 | .115 | .153 | .696 |
| Academic Standing*Course | 0 | 0 | 0 | 0 |
| Academic Standing*Gender | 1 | .001 | .002 | .965 |
| Race*Age | 1 | .120 | .160 | .690 |
| Race*Pre/Post | 1 | .029 | .039 | .844 |
| **Race*Group** | **1** | **3.214** | **4.268** | **.040** |
| Race*Course | 1 | 2.237 | 2.971 | .086 |
| Race*Gender | 1 | .021 | .027 | .869 |
| Age*Pre/Post | 1 | .098 | .130 | .719 |
| Age*Group | 1 | .525 | .698 | .405 |
| Age*Course | 0 | 0 | 0 | 0 |
| Age*Gender | 1 | .449 | .596 | .441 |
| Pre/Post*Group | 1 | 1.298 | 1.724 | .191 |
| **Pre/Post*Course** | **1** | **9.387** | **12.467** | **< .001** |
| Pre/Post*Gender | 1 | .136 | .180 | .671 |
| **Group*Course** | **1** | **6.583** | **8.744** | **.004** |

| | | | | |
|---|---|---|---|---|
| Group*Gender | 1 | .008 | .011 | .918 |
| Course*Gender | 1 | .004 | .005 | .943 |

**Appendix E: ANOVA Table for Biology Self-Efficacy**

*Table A4. ANOVA Results for Biology Self-Efficacy. Significant factors noted by bold font.*

| | df | Mean Square | F | Significance |
|---|---|---|---|---|
| **Interest in Entrepreneurship** | **1** | **3.134** | **4.189** | **.042** |
| **Academic Standing** | **1** | **4.251** | **5.682** | **.018** |
| Race | 1 | .024 | .032 | .858 |
| Age | 1 | 2.201 | 2.942 | .088 |
| Pre/Post | 1 | .199 | .266 | .607 |
| Group | 1 | .540 | .721 | .397 |
| **Course** | **1** | **6.305** | **8.428** | **.004** |
| Gender | 2 | .823 | 1.099 | .335 |
| Interest in Entrepreneurship*Academic Standing | 1 | 1.405 | 1.878 | .172 |
| Interest in Entrepreneurship*Race | 1 | .499 | .667 | .415 |
| Interest in Entrepreneurship*Age | 1 | .062 | .083 | .774 |
| Interest in Entrepreneurship*Pre/Post | 1 | .195 | .261 | .610 |
| Interest in Entrepreneurship*Group | 1 | 2.409 | 3.220 | .074 |

| | | | | |
|---|---|---|---|---|
| Interest in Entrepreneurship*Course | 1 | .001 | .001 | .972 |
| Interest in Entrepreneurship*Gender | 1 | .315 | .421 | .517 |
| Academic Standing*Race | 1 | .742 | .991 | .321 |
| Academic Standing*Age | 1 | .036 | .048 | .827 |
| Academic Standing*Pre/Post | 0 | .284 | .379 | .539 |
| Academic Standing*Group | 1 | .094 | .125 | .724 |
| Academic Standing*Course | 0 | 0 | 0 | 0 |
| Academic Standing*Gender | 1 | .087 | .117 | .733 |
| Race*Age | 1 | .494 | .660 | .418 |
| Race*Pre/Post | 1 | .019 | .026 | .872 |
| Race*Group | 1 | .013 | .018 | .894 |
| Race*Course | 1 | 1.075 | 1.437 | .232 |
| Race*Gender | 1 | .001 | .002 | .965 |
| Age*Pre/Post | 1 | .068 | .091 | .764 |
| Age*Group | 1 | .057 | .076 | .783 |
| Age*Course | 0 | 0 | 0 | 0 |
| Age*Gender | 1 | .090 | .120 | .730 |
| Pre/Post*Group | 1 | .205 | .274 | .602 |
| Pre/Post*Course | 1 | .410 | .548 | .460 |
| Pre/Post*Gender | 1 | 1.415 | 1.892 | .171 |

| | | | | |
|---|---|---|---|---|
| **Group*Course** | **1** | **3.903** | **5.217** | **.024** |
| Group*Gender | 1 | .031 | .041 | .839 |
| Course*Gender | 1 | .006 | .008 | .930 |

**Appendix F: Instruments used to measure grit, retention, biology interest, and biology self-efficacy.**

*Pre-survey*

You are being invited to participate in a **research** study titled "Does Entrepreneurship Education Impact Undergraduate Interest and Retention in Biology?" being conducted by Elliot Weinthal, a graduate student at East Carolina University in the Biology department, and Dr. Heather Vance-Chalcraft, a faculty member at East Carolina University in the Biology department. The research involves four canvas modules spread out over four weeks, each one should take 10-15 minutes to complete and are followed by a short quiz. There are two different sets of modules, one will cover entrepreneurial content and the other will cover financial literacy. There will be two surveys, a pre-intervention survey and a post-intervention survey. The goal is to have up to 750 undergraduate students participate in the study. The surveys will take approximately 15 minutes to complete. Mr. Weinthal will also interview up to 30 additional volunteers in a focus group. It is hoped that this information will provide a deeper understanding of how the use of entrepreneurship interventions for biology undergraduates impacts biological self-efficacy, interest, and retention in the major. Your responses to the surveys will be kept confidential and no data will be released or used with your identification attached. Your participation in the research is **voluntary**. You may choose not to answer any or all questions, and you may stop at any time. There is **no penalty for not taking part** in this research study. Students under 18 years of age are not eligible to participate. Please call Dr. Heather Vance-Chalcraft at 252-328-9841 for any research-related questions or the Office of Research Integrity & Compliance (ORIC) at 252-744-2914 for questions about your rights as a research participant.

Demographics

1. What is your age in years?
Free Response

2. What is your gender?
A. Male
B. Female
C. Other

3. Which race best describes you?
A. Asian/Asian American
B. Black/African American
C. Hawaiian/Pacific Islander
D. Native American/Alaskan native
E. White/Caucasian
F. Other

4. Which ethnicity best describes you?
A. Hispanic, Latina/o, Chicana/o
B. Not Hispanic, Latina/o, Chicana/o

5. What is your student classification (based on semester hours)?
A. Freshman
B. Sophomore
C. Junior
D. Senior

**Entrepreneurship History**
6. Have you ever participated in an entrepreneurship program?
A. Yes
B. No
C. Not sure

7. Has anyone in your immediate family started their own business?
A. Yes
B. No
C. Not sure

8. Have any of your close friends started their own business?
A. Yes
B. No
C. Not sure

9. Have you ever participated in an innovation program?
A. Yes
B. No
C. Not sure

10. Have you ever thought of starting your own business?
A. Yes
B. No
C. Not sure

11. Is the sky blue?
A. Yes
B. No
C. Not sure

12. Have you ever thought of developing your own product?
A. Yes
B. No
C. Not sure

13. How confident are you in using your scientific knowledge to develop a product?
A. Very unconfident
B. Somewhat unconfident
C. Neither unconfident or confident
D. Somewhat confident
E. Very confident

Biology Interest Scale
1. How interested are you in biology?
A. Very uninterested
B. Somewhat uninterested
C. Neither uninterested or interested
D. Somewhat interested
E. Very interested

2. How likely is it you will stay a biology major?
A. Highly unlikely
B. Somewhat unlikely
C. Neither likely or unlikely
D. Somewhat likely
E. Highly likely

3. I do not talk about biology outside of school
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

4. I do not read about biology outside of school
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

5. I follow science pages on social media
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

6. I do not enjoy learning about biology
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

7. I look forward to my biology classes
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

<u>Brief Index of Student Retention</u>
All items from this scale were used and can be found in the second paragraph of the Validity Subsample section on page 59 of Davidson & Beck 2021.

<u>Biology Self-Efficacy Instrument for Nonmajors</u>
All items from this scale were used and can be found in Appendix: Self-Efficacy Instrument of Baldwin et al., 1999.

<u>Grit-S Scale</u>
All items from this scale were used and are the italicized items in Table 1 of Duckworth and Quinn 2009.

***<u>Post-Survey</u>***
<u>Entrepreneurship History</u>
1. Do you feel more confident in using your scientific knowledge to develop a product?
A. Yes
B. No
C. Unsure

2. How likely is it that you will pursue entrepreneurship as a career in STEM?
A. Highly unlikely
B. Somewhat unlikely
C. Neither likely or unlikely
D. Somewhat likely
E. Highly likely

3. How confident are you in using your scientific knowledge to develop a product?
A. Very unconfident
B. Somewhat unconfident
C. Neither unconfident or confident
D. Somewhat confident
E. Very confident

Biology Interest

1. How interested are you in biology?
A. Very uninterested
B. Somewhat uninterested
C. Neither uninterested or interested
D. Somewhat interested
E. Very interested

2. How likely is it you will stay a biology major?
A. Highly unlikely
B. Somewhat unlikely
C. Neither likely or unlikely
D. Somewhat likely
E. Highly likely

3. I do not talk about biology outside of school
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

4. I do not read about biology outside of school
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

5. I follow science pages on social media
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

6. I do not enjoy learning about biology
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

7. I look forward to my biology classes
A. Very inaccurate
B. Somewhat inaccurate
C. Neither inaccurate or accurate
D. Somewhat accurate
E. Very accurate

Brief Index of Student Retention
All items from this scale were used and can be found in the second paragraph of the Validity Subsample section on page 59 of Davidson & Beck 2021.

Biology Self-Efficacy Instrument for Nonmajors
All items from this scale were used and can be found in Appendix: Self-Efficacy Instrument of Baldwin et al., 1999.

Grit-S Scale
All items from this scale were used and are the italicized items in Table 1 of Duckworth and Quinn 2009.

## Appendix G: Focus Group Script

Focus groups will be in groups of 7-8 individuals who have completed the post-intervention survey. Groups will be welcomed and then given a brief explanation of the format of the focus group: Open discussion that will last approximately one hour with 7 questions total, followed by clarifying questions, as needed.

Question 1: Do you have any interest in the relationship between biology and entrepreneurship?

Question 2: Is career potential important in your decision of major?

Question 3: Are you more likely to stay in the biology major if you see a range of careers are possible?

Question 4: Do you feel equipped with the skills to apply your biological knowledge to real world problems?
Question 5: Does the idea of using biology to solve real world problems make you more interested in the major?

Question 6: Do you feel learning to apply your biological education makes you more confident in your biological knowledge?

Question 7: Do you feel entrepreneurship content would be more beneficial later in your academic career (junior/senior) as opposed to now (freshman/sophomore)?