Supplementary materials for

Authentic STEM research, practices of science, and interest development in an informal science education program

Methods supplement. Research team participants were administered surveys during three time points as shown below: (1) before participation in the research team (baseline survey); (2) following the summer session (midpoint survey); and (3) following the fall session (post survey)

Landscape Genetics and Species Diversity
of Macroinvertebrates and Fishes of New York Harbor
Baseline Survey

Name: _____ **Date:** _____ **Lang Team #:** _____

Was this your 1st, 2nd, or 3rd choice as a research team? _____

Please indicate all the other research teams that you have participated in during Lang:

_____
_____

Please indicate all research experiences that you have participated in outside of Lang, either at school, on your own, or in another program:

_____
_____

What topics are you interested in studying in the future?

_____
_____

What careers are you most interested in pursuing in the future?

_____
_____

What was your motivation for joining this research team?

_____
_____
_____
_____
_____
_____

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Literature Review and Search	☐	☐	☐	☐
Extracting Information From a Journal Article (Annotated Bibliography)	☐	☐	☐	☐
Pipetting	☐	☐	☐	☐
Keeping a Lab Notebook	☐	☐	☐	☐
Water Quality Testing (e.g. measuring salinity dissolved oxygen, nitrate, etc.)	☐	☐	☐	☐
DNA Extraction	☐	☐	☐	☐
Polymerase Chain Reaction (PCR) Amplification	☐	☐	☐	☐
Gel Electrophoresis	☐	☐	☐	☐
Standard Morphological Measurements of Fishes and Invertebrates	☐	☐	☐	☐

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Sample Collection using Beach Seine, Cast Nets, Dip Nets, Fish Traps, and Crab Nets	☐	☐	☐	☐
Using Field Guides to Identify Invertebrates, Fishes and Coastal Animals	☐	☐	☐	☐
Writing a Research Proposal	☐	☐	☐	☐
Constructing Phylogenetic Trees	☐	☐	☐	☐
Using the R Program for Statistical Computing	☐	☐	☐	☐
Measuring biodiversity (Alpha Diversity, Simpson Index, Shannon-Wiener Index, Evenness)	☐	☐	☐	☐
Creating a Research Poster	☐	☐	☐	☐
Writing a Research Article for a Peer-Reviewed Journal	☐	☐	☐	☐

Interest
Please check the box that best describes your level of interest for each of the following:

	I am not very interested in this topic	I think I might be interested in this topic	I am excited about learning more about this topic	I have a deep interest in this topic
Scientific Research	☐	☐	☐	☐
Landscape Genetics	☐	☐	☐	☐
Field Biology	☐	☐	☐	☐
Ecology	☐	☐	☐	☐

Engagement
Please check the box that best describes your level of engagement for each of the following:

	Rarely	Sometimes (monthly)	Often (weekly)	Very Often (almost daily)
I read articles about scientific research <u>on my own</u>	☐	☐	☐	☐
I discuss scientific research with my friends outside of school/Lang	☐	☐	☐	☐
I discuss scientific research with my family	☐	☐	☐	☐
I think about science-related questions and problems	☐	☐	☐	☐

Landscape Genetics and Species Diversity
of Macroinvertebrates and Fishes of New York Harbor
Midpoint Survey

Name: _____ Date: _____ Lang Team #: _____

So far you have finished two weeks of a research team focused on landscape genetics and species diversity. How has the experience thus far impacted your motivation for engaging in scientific research? Please provide a detailed answer.

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Still need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Literature Review and Search	☐	☐	☐	☐
Extracting Information From a Journal Article (Annotated Bibliography)	☐	☐	☐	☐
Pipetting	☐	☐	☐	☐
Keeping a Lab Notebook	☐	☐	☐	☐
Water Quality Testing (e.g. measuring salinity dissolved oxygen, nitrate, etc.)	☐	☐	☐	☐
DNA Extraction	☐	☐	☐	☐
Polymerase Chain Reaction (PCR) Amplification	☐	☐	☐	☐
Gel Electrophoresis	☐	☐	☐	☐
Standard Morphological Measurements of Fishes and Invertebrates	☐	☐	☐	☐

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Sample Collection using Beach Seine, Cast Nets, Dip Nets, Fish Traps, and Crab Nets	☐	☐	☐	☐
Using Field Guides to Identify Invertebrates, Fishes and Coastal Animals	☐	☐	☐	☐
Writing a Research Proposal	☐	☐	☐	☐
Constructing Phylogenetic Trees	☐	☐	☐	☐
Using the R Program for Statistical Computing	☐	☐	☐	☐
Measuring biodiversity (Alpha Diversity, Simpson Index, Shannon-Wiener Index, Evenness)	☐	☐	☐	☐
Creating a Research Poster	☐	☐	☐	☐
Writing a Research Article for a Peer-Reviewed Journal	☐	☐	☐	☐

Interest
Please check the box that best describes your level of interest for each of the following:

	I am not very interested in this topic	I think I might be interested in this topic	I am excited about learning more about this topic	I have a deep interest in this topic
Scientific Research	☐	☐	☐	☐
Landscape Genetics	☐	☐	☐	☐
Field Biology	☐	☐	☐	☐
Ecology	☐	☐	☐	☐

Engagement
Please check the box that best describes your level of engagement for each of the following:

	Rarely	Sometimes (monthly)	Often (weekly)	Very Often (almost daily)
I read articles about scientific research <u>on my own</u>	☐	☐	☐	☐
I discuss scientific research with my friends outside of school/Lang	☐	☐	☐	☐
I discuss scientific research with my family	☐	☐	☐	☐
I think about science-related questions and problems	☐	☐	☐	☐

Landscape Genetics and Species Diversity
of Macroinvertebrates and Fishes of New York Harbor
Post Survey

Name: _____ Date: _____ Lang Team #: _____

Now that you have completed participation in a research team focused on landscape genetics and species diversity, how has the experience impacted your motivation for engaging in scientific research? Please provide a detailed answer.

What topics are you interested in studying in the future?

What careers are you most interested in pursuing in the future?

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Still need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Literature Review and Search	☐	☐	☐	☐
Extracting Information From a Journal Article (Annotated Bibliography)	☐	☐	☐	☐
Pipetting	☐	☐	☐	☐
Keeping a Lab Notebook	☐	☐	☐	☐
Water Quality Testing (e.g. measuring salinity dissolved oxygen, nitrate, etc.)	☐	☐	☐	☐
DNA Extraction	☐	☐	☐	☐
Polymerase Chain Reaction (PCR) Amplification	☐	☐	☐	☐
Gel Electrophoresis	☐	☐	☐	☐
Standard Morphological Measurements of Fishes and Invertebrates	☐	☐	☐	☐

Skills and Practices
Please check which best describes your experience using the following scientific practices:

	Need to learn	Need to review	I can do it without review	I can do it without review AND I can also teach others
Sample Collection using Beach Seine, Cast Nets, Dip Nets, Fish Traps, and Crab Nets	☐	☐	☐	☐
Using Field Guides to Identify Invertebrates, Fishes and Coastal Animals	☐	☐	☐	☐
Writing a Research Proposal	☐	☐	☐	☐
Constructing Phylogenetic Trees	☐	☐	☐	☐
Using the R Program for Statistical Computing	☐	☐	☐	☐
Measuring biodiversity (Alpha Diversity, Simpson Index, Shannon-Wiener Index, Evenness)	☐	☐	☐	☐
Creating a Research Poster	☐	☐	☐	☐
Writing a Research Article for a Peer-Reviewed Journal	☐	☐	☐	☐

Interest
Please check the box that best describes your level of interest for each of the following:

	I am not very interested in this topic	I think I might be interested in this topic	I am excited about learning more about this topic	I have a deep interest in this topic
Scientific Research	☐	☐	☐	☐
Landscape Genetics	☐	☐	☐	☐
Field Biology	☐	☐	☐	☐
Ecology	☐	☐	☐	☐

Engagement
Please check the box that best describes your level of engagement for each of the following:

	Rarely	Sometimes (monthly)	Often (weekly)	Very Often (almost daily)
I read articles about scientific research <u>on my own</u>	☐	☐	☐	☐
I discuss scientific research with my friends outside of school/Lang	☐	☐	☐	☐
I discuss scientific research with my family	☐	☐	☐	☐
I think about science-related questions and problems	☐	☐	☐	☐

Self-Directed Research
As a result of completing this research project, to what extent do you envision yourself doing the following?

	Rarely	Sometimes (monthly)	Often (weekly)	Very Often (almost daily)
Learning to code more	☐	☐	☐	☐
Looking up current research articles on biodiversity, ecology and/or genetics)	☐	☐	☐	☐
Looking up scientists who study this research (biodiversity, ecology, and/or genetics)	☐	☐	☐	☐

Future Participation
If you had a choice to rejoin this research project next year (either as a high school student or college freshman), which would you choose?

	I would not rejoin	I'm not sure	I would like to rejoin but might try something new	I would definitely rejoin
Rejoin research team?	☐	☐	☐	☐

If you had a choice to join a research lab in college in either biodiversity or ecology or landscape genetics, which would you choose?

	I would not join	I'm not sure	I would like to join a lab but might try a different topic	I would definitely join
Join a similar research team in college?	☐	☐	☐	☐

Methods supplement. We developed interview questions, as shown below, based on the four behavioral indicators suggested by Renninger and Hidi (2016): (1) frequency of engagement; (2) depth of engagement; (3) voluntary engagement; and (4) capacity for independent reengagement.

INTERVIEW QUESTIONS FOR LANG RESEARCH TEAM MEMBERS

FREQUENCY OF ENGAGEMENT

1. Would you characterize your overall attendance as: consistent, inconsistent, or somewhere in between? Why do you think this is so?
2. Would you have preferred more sessions or fewer sessions to work on your project? Why?

DEPTH OF ENGAGEMENT

1. Think back to the first day of the Lang Research Team. In retrospect, do you think your interest in research has increased, remained the same, or decreased as a result of this experience? Explain.
2. If you were to continue with your research project (part two), how much support would you need from an expert and how much do you think you could complete on your own?
3. How comfortable do you feel teaching the content you learned during your research team to another student? Explain.

VOLUNTARY ENGAGEMENT

1. What was your motivation for joining and for your continued participation in this research team?
2. Did you attend any of the voluntary sessions? What were your reasons for attending or not attending these sessions?
3. Looking back, are there any reasons why you would not have opted to participate in this research team (for example, if your friends hadn't joined, if your parents wanted you to do something different, and/or is there was another research team on a different topic or related to a school project)?
4. If you had a chance to rejoin this research project next year (either as a high school student or college freshman), which would you choose? Why?
5. If you had a chance to join a research lab in college either in biodiversity or coding or ecology or landscape genetics, which would you choose? Why?

CAPACITY FOR INDEPENDENT ENGAGEMENT

1. Describe what work you did during the research team and what work you did at home or on weekends.
2. Would you characterize the amount of time that you needed to work on this project outside of Lang as a lot, a little, or somewhere in between? Why do you think this is so?
3. How often, if at all, do you presently read articles about and/or discuss biodiversity or landscape genetics or ecology or coding with others, or engage in any other activities related to the research team outside of Lang? Why do you think this is so?
4. Do you foresee yourself doing related research – such as biodiversity, genetics, ecology, or coding – in the future or do you think you will be doing something different? Explain.

Fig. S1 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of conducting a literature review. There was no significant difference over time (baseline vs. midpoint: p=0.999; midpoint vs. post: p=0.087; baseline vs. post: p=0.087).

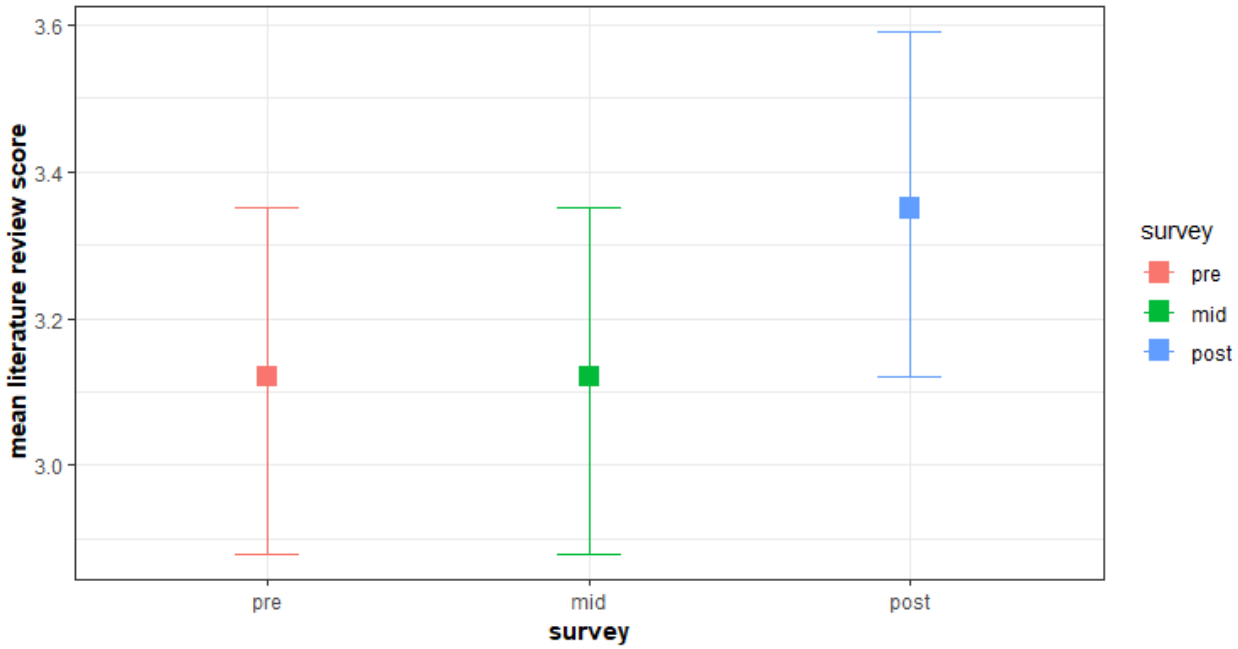

Fig. S2 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of extracting information from a journal article (annotated bibliography). Participants exhibited significant improvement over time (baseline vs. post: p=0.007).

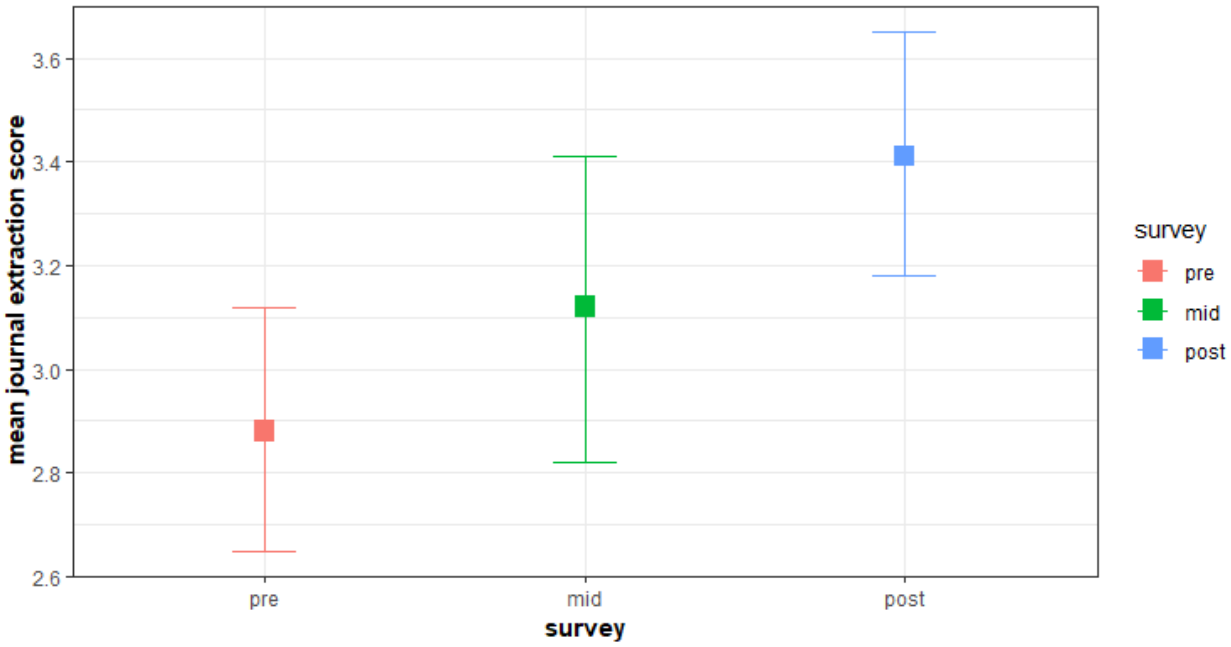

Fig. S3 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of pipetting. Participants exhibited significant improvement over two different time points (baseline vs. midpoint: p=0.006; baseline vs. post: p=0.006).

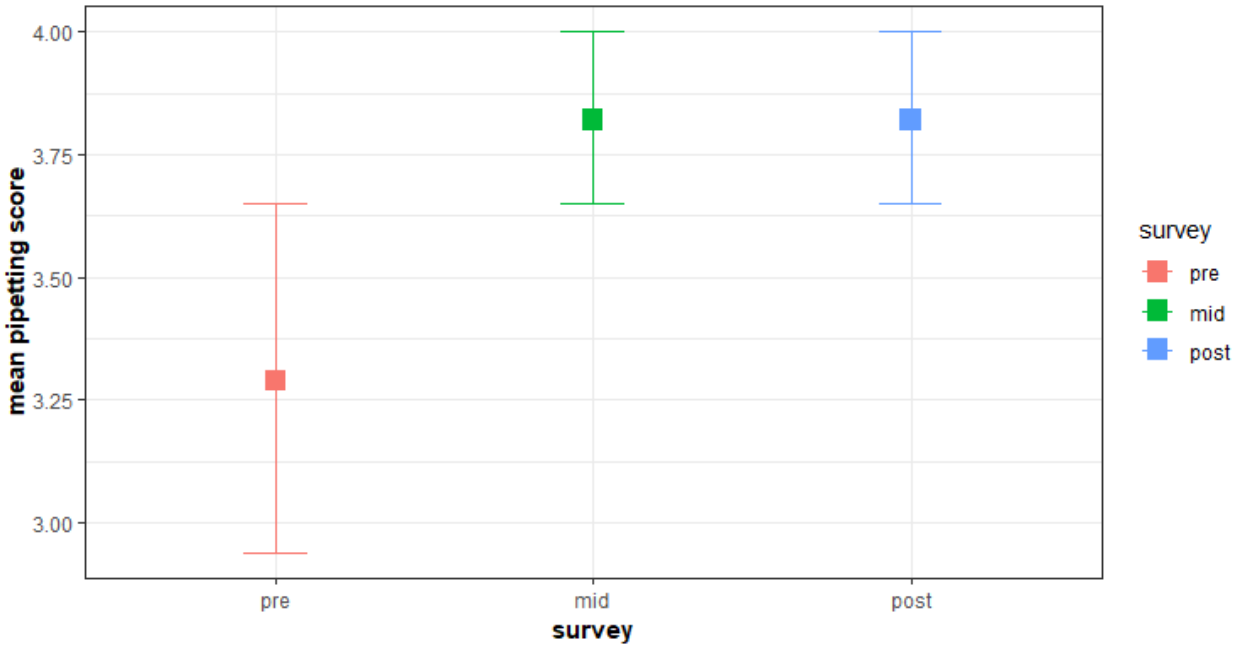

Fig. S4 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of keeping a lab notebook. Participants exhibited significant improvement over two different time points (baseline vs. midpoint: $p=0.024$; baseline vs. post: $p<0.001$).

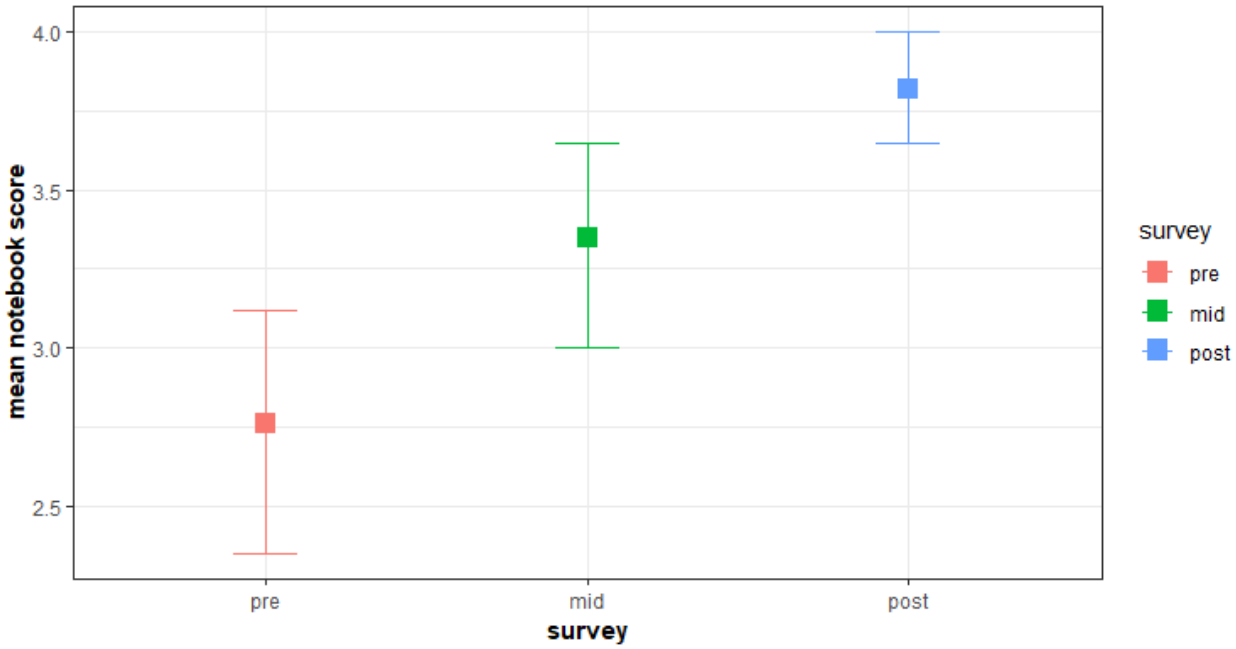

Fig. S5 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of water quality testing (e.g. measuring salinity, dissolved oxygen, nitrate, etc.). Participants exhibited significant improvement over two different time points (baseline vs. midpoint: $p=0.005$; baseline vs. post: $p<0.001$).

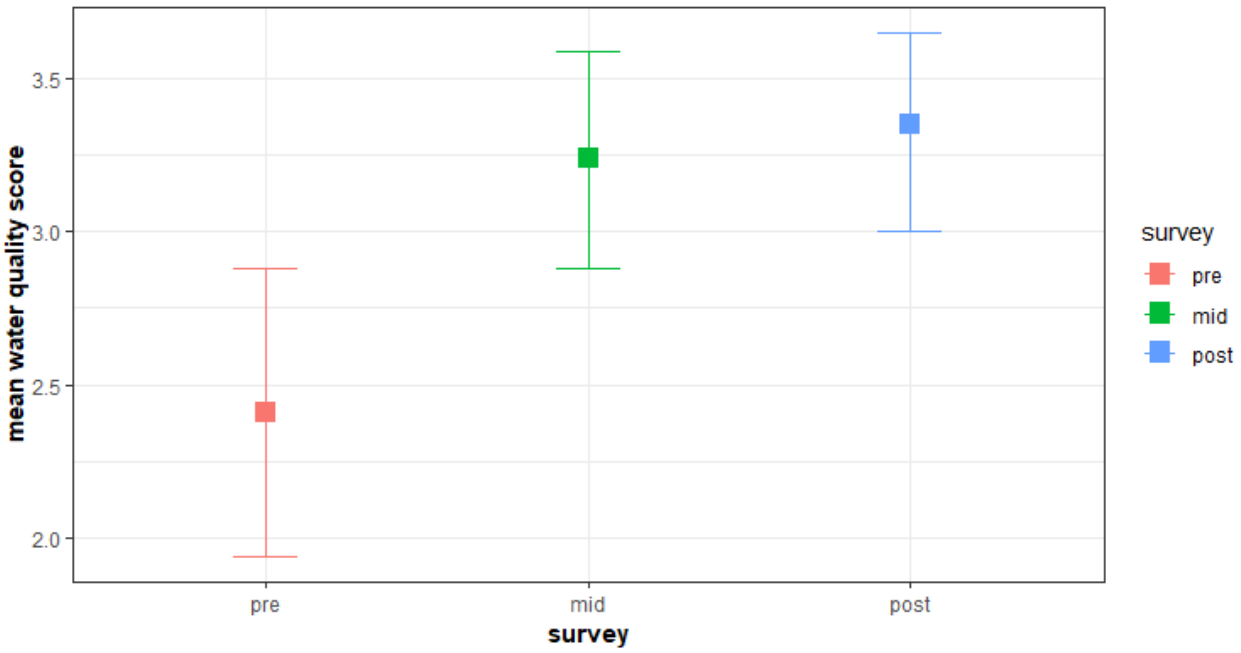

Fig. S6 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of DNA extraction. Participants exhibited significant improvement over two different time points (baseline vs. midpoint: $p<0.001$; baseline vs. post: $p<0.001$).

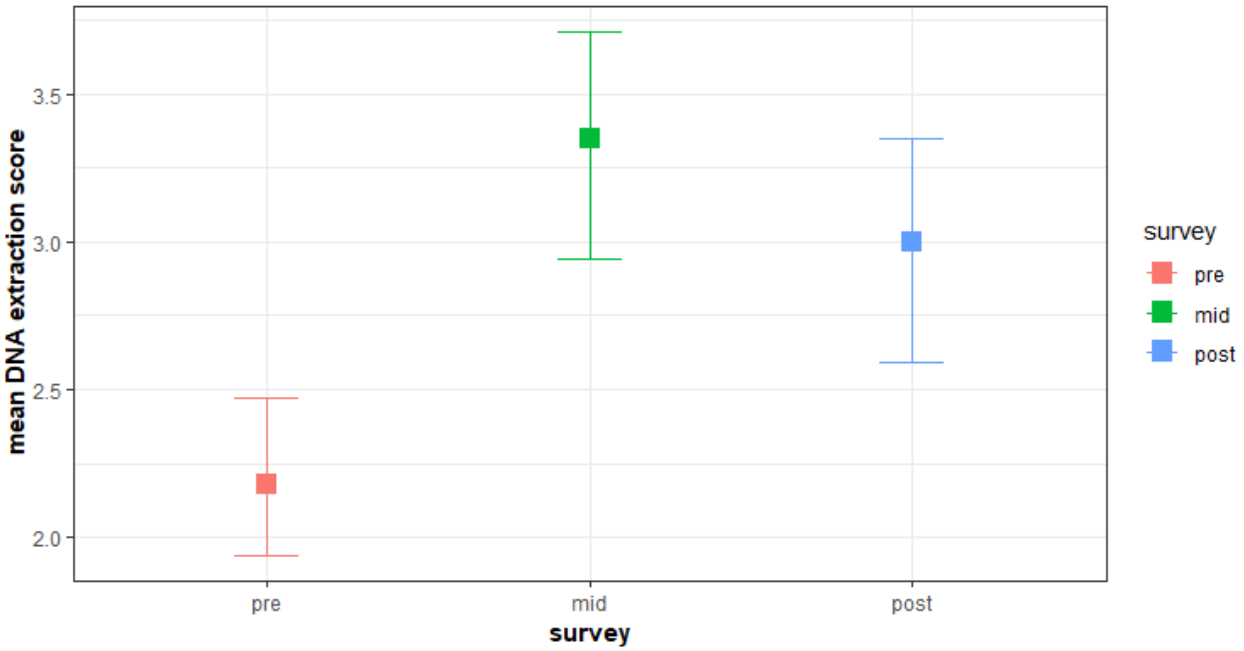

Fig. S7 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of polymerase chain reaction (PCR) amplification. Participants exhibited significant improvement over time (baseline vs. post: $p<0.001$).

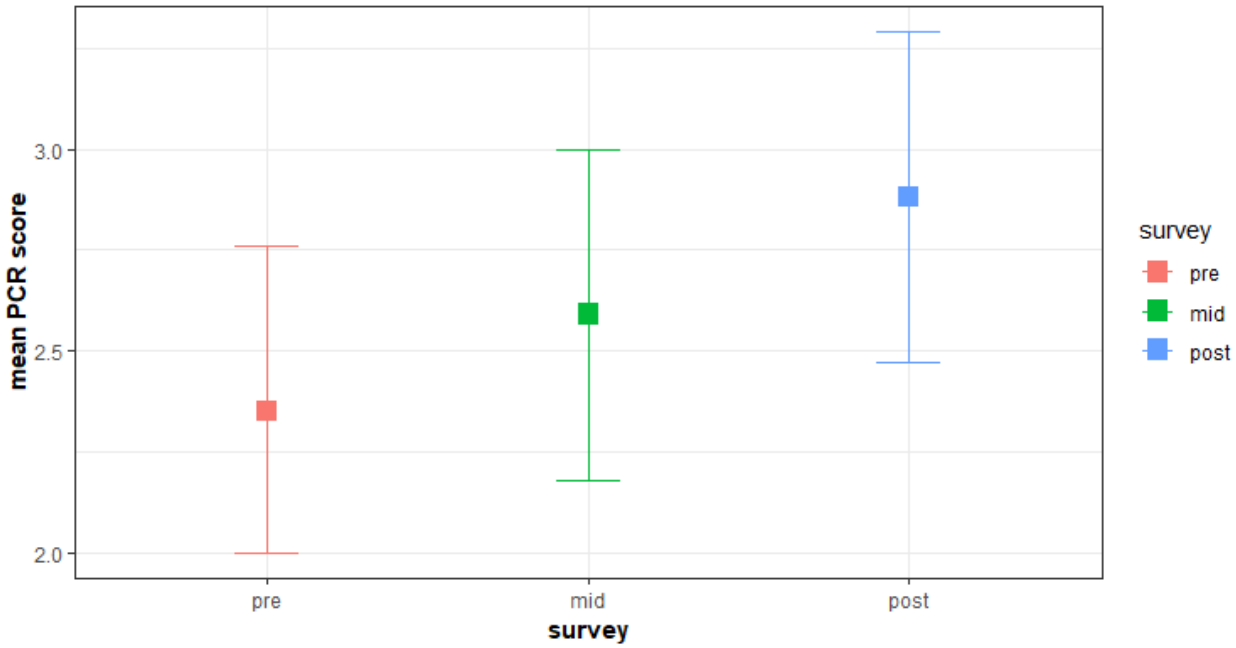

Fig. S8 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of gel electrophoresis. There was no significant difference over time (baseline vs. midpoint: p=0.569; midpoint vs. post: p=0.569; baseline vs. post: p=0.107).

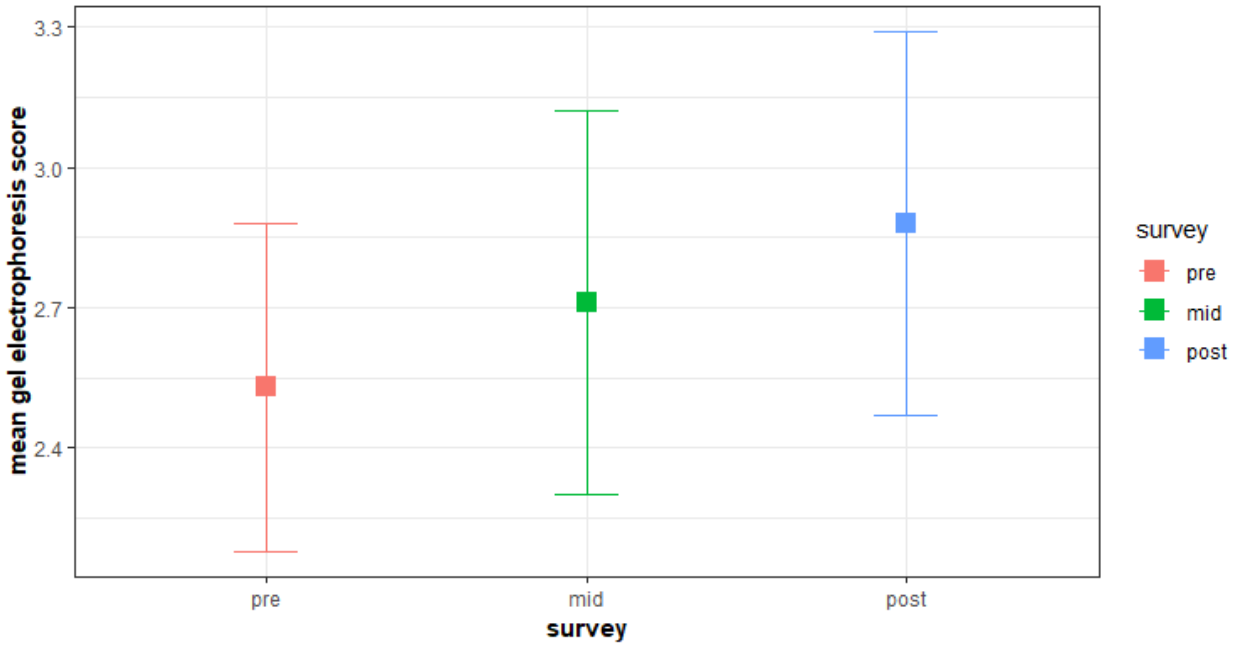

Fig. S9 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of standard morphological measurements of fishes and invertebrates. Participants exhibited significant improvement over two different time points (baseline vs. midpoint: $p<0.001$; baseline vs. post: $p<0.001$).

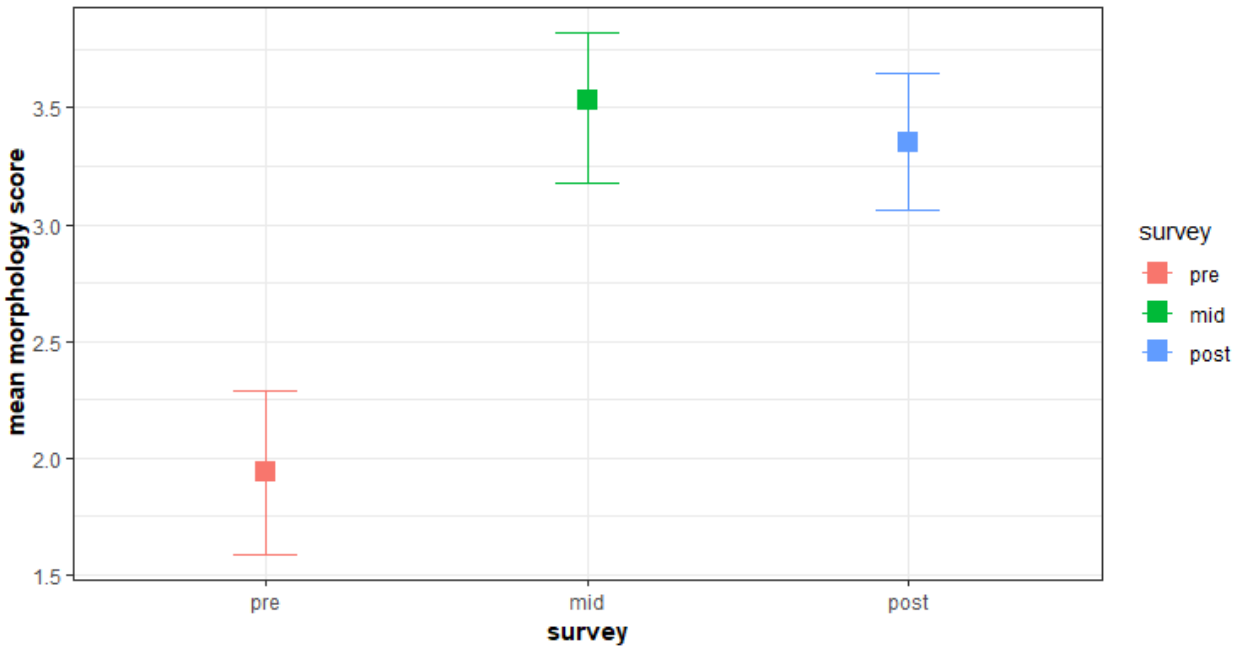

Fig. S10 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of sample collection using a seine, cast nets, dip nets, fish traps, and crab nets. Participants exhibited significant improvement over two different time points (baseline vs. midpoint: $p<0.001$; baseline vs. post: $p<0.001$).

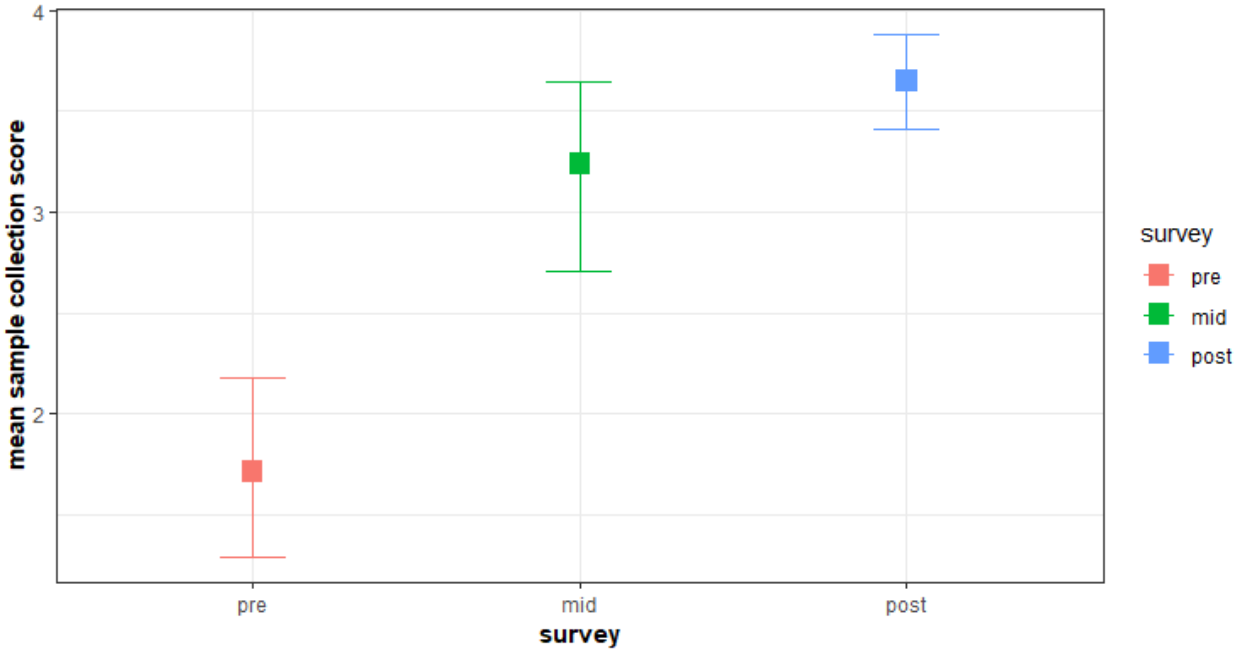

Fig. S11 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of using a field guide to identify invertebrates, fishes, and coastal animals. Participants exhibited significant improvement over three different time points (baseline vs. midpoint: p=0.013; midpoint vs. post: p=0.032; baseline vs. post: p<0.001).

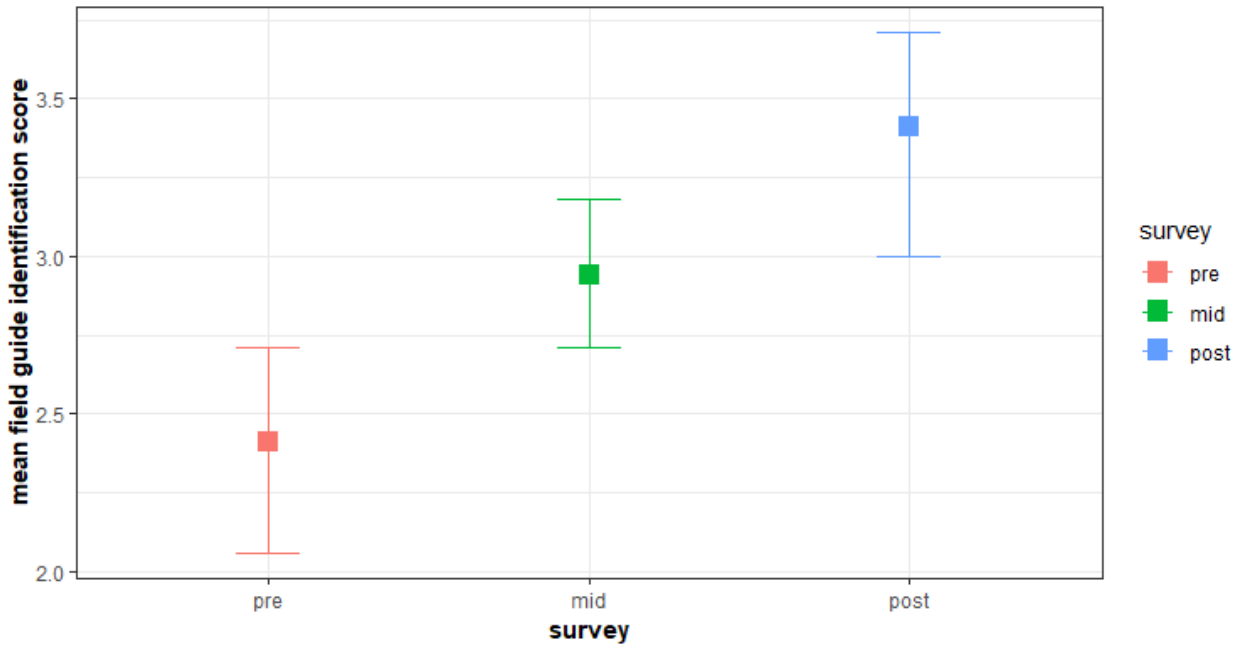

Fig. S12 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of writing a research proposal. Participants exhibited significant improvement over two different time points (midpoint vs. post: p=0.005; baseline vs. post: p=0.014).

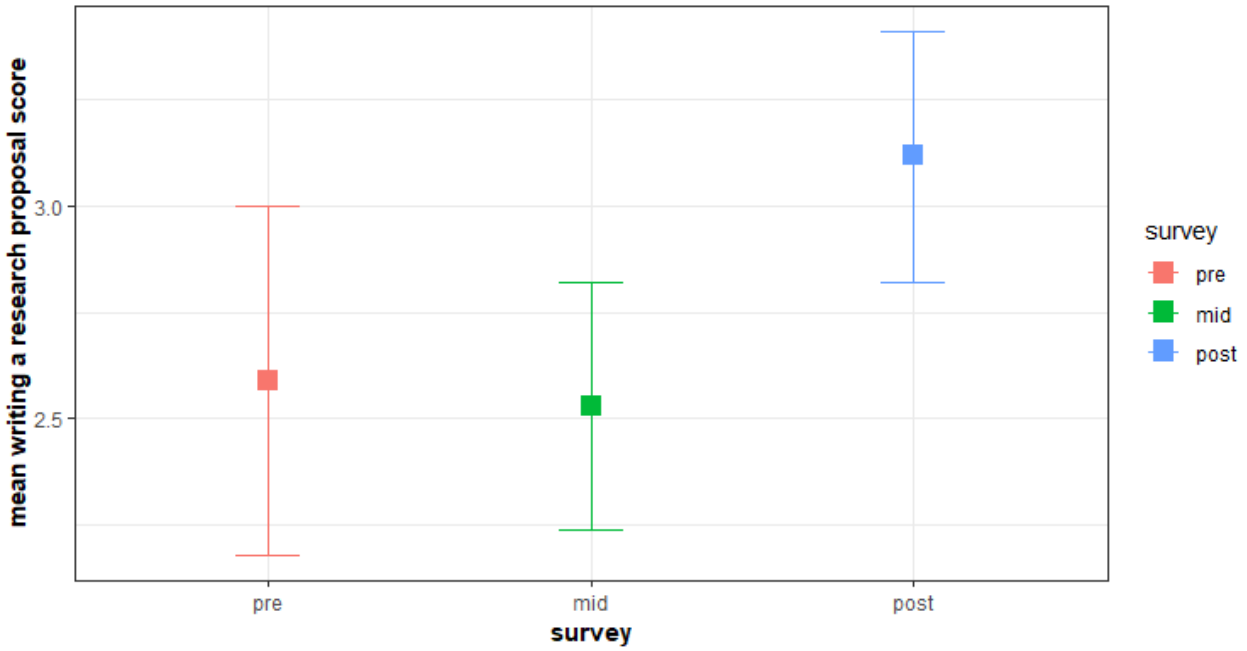

Fig. S13 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of constructing phylogenetic trees. Participants exhibited significant improvement over time (midpoint vs. post: p=0.028).

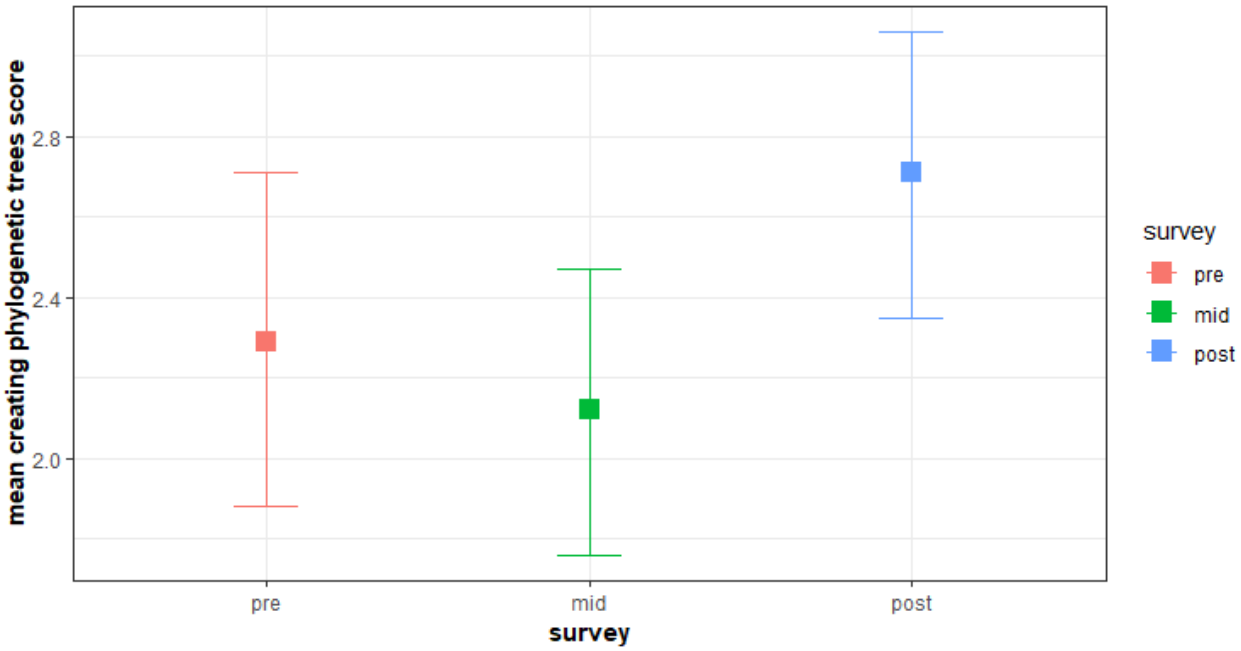

Fig. S14 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of using the R Program for Statistical Computing. Participants exhibited significant improvement over two different time points (midpoint vs. post: $p<0.001$; baseline vs. post: $p<0.001$).

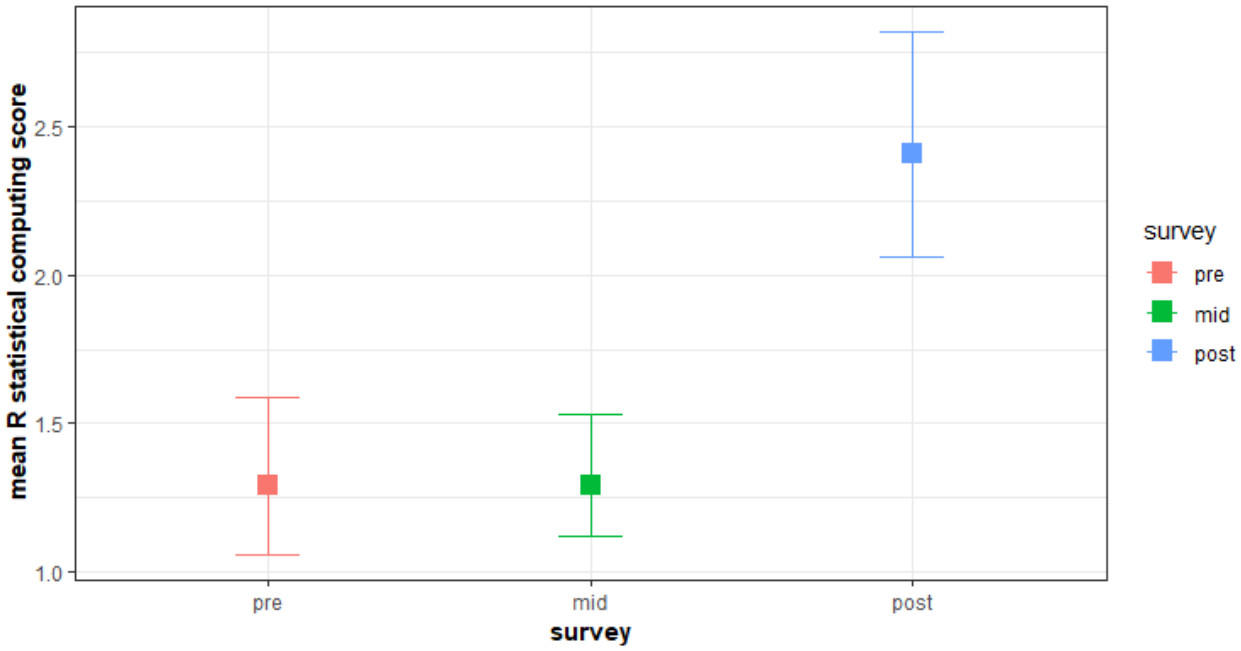

Fig. S15 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of measuring biodiversity (alpha diversity, Simpson index, Shannon-Weiner index, evenness). Participants exhibited significant improvement over two different time points (midpoint vs. post: $p<0.001$; baseline vs. post: $p<0.001$).

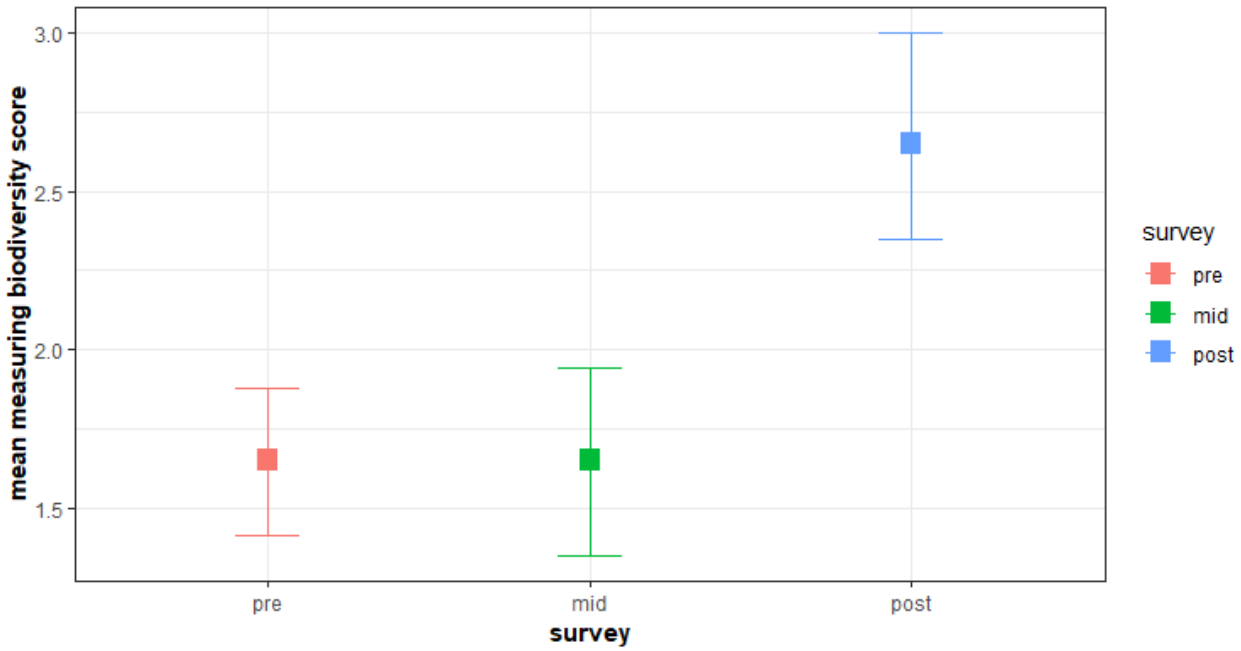

Fig. S16 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of creating a research poster. Participants exhibited significant improvement over time (baseline vs. post: p=0.006).

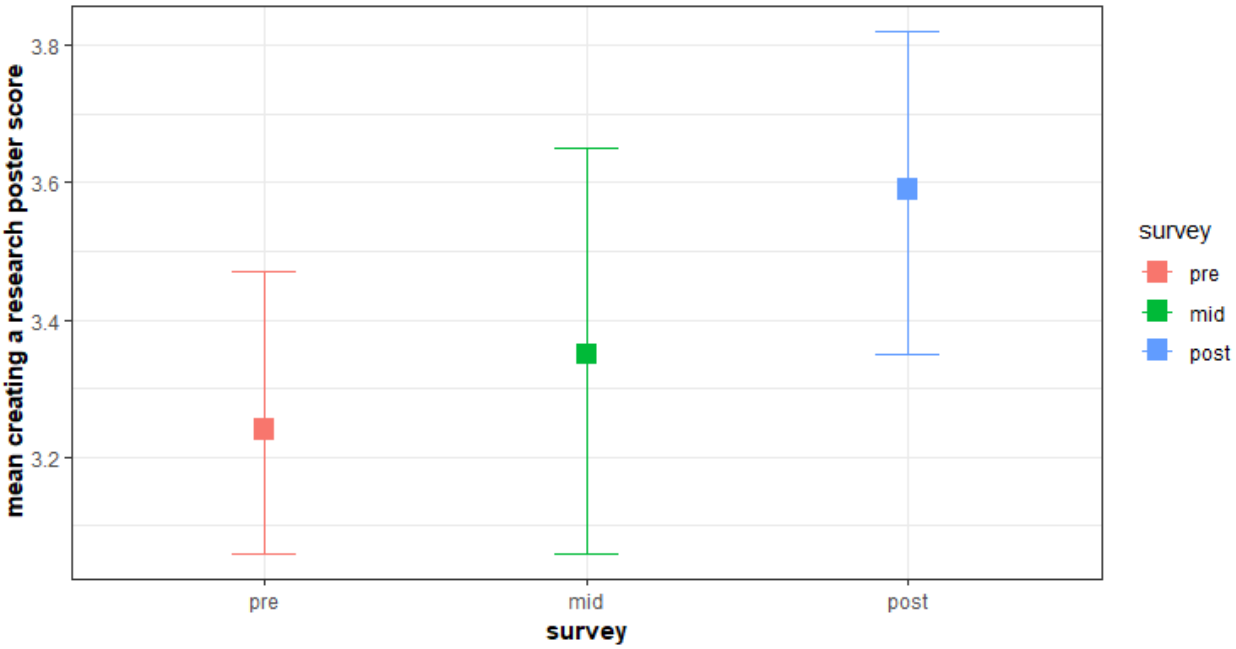

Fig. S17 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' level of competence in mastering the skill of writing a research article for a peer-reviewed journal. Participants exhibited significant improvement over two different time points (midpoint vs. post: p=0.015; baseline vs. post: p=0.015).

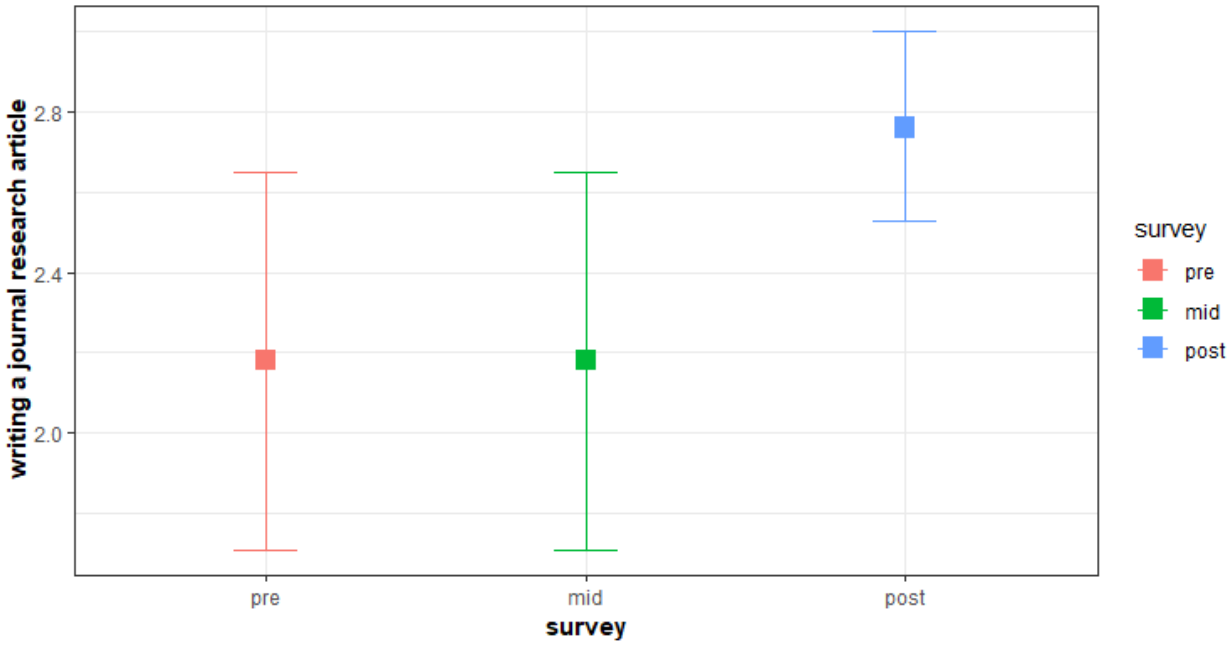

Fig. S18 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' engagement in the skills and practices of science outside the scope of the program over time. Participants exhibited significant increases in the amount of time in which they read scientific articles outside the scope of the program (midpoint vs. post: p=0.049).

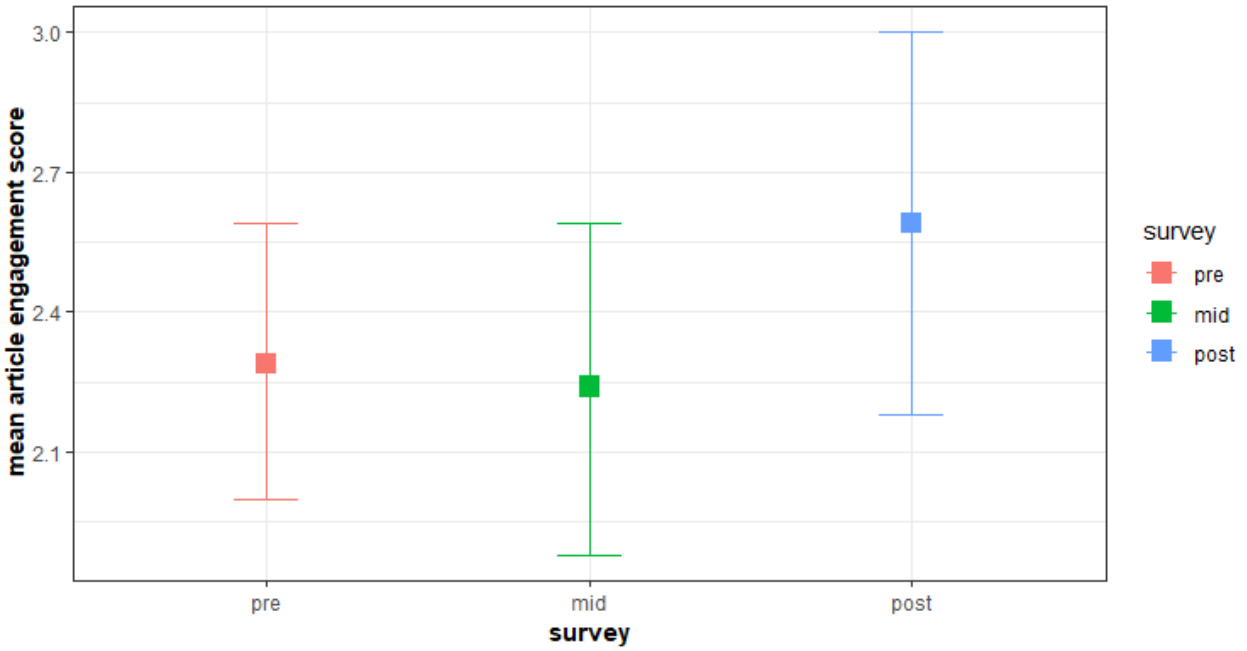

Fig. S19 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' engagement in the skills and practices of science outside the scope of the program over time. Participants exhibited significant increases in the amount of time in which they discussed scientific research with their friends outside the scope of the program (baseline vs. post: p=0.003).

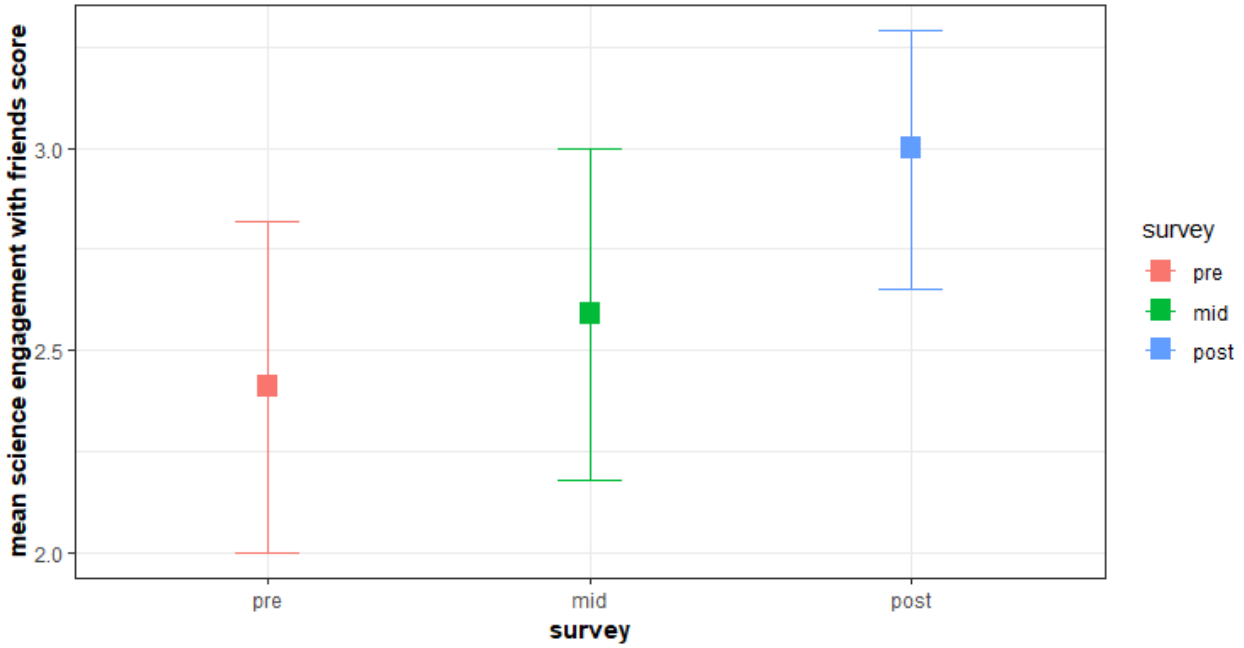

Fig. S20 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' engagement in the skills and practices of science outside the scope of the program over time. There was no significant increase in the amount of time that research team members discussed scientific research with their family in non-program contexts (baseline vs. midpoint: p=0.421; midpoint vs. post: p=0.805; baseline vs. post: p=0.144).

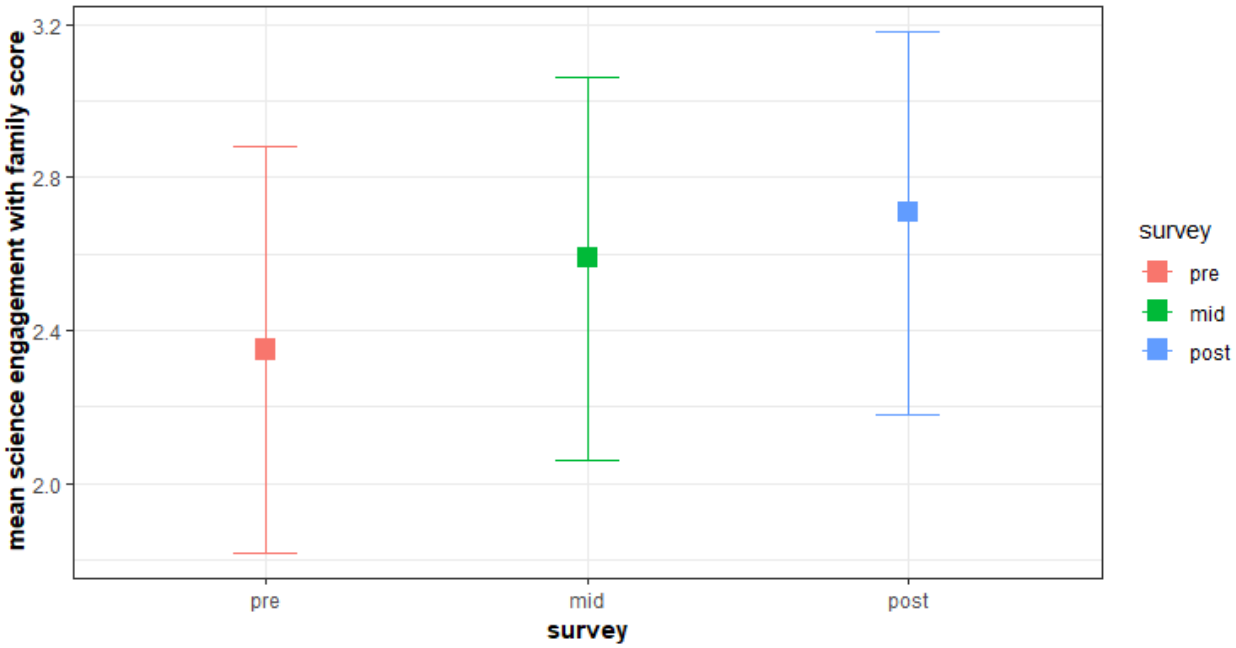

Fig. S21 A repeated measures ANOVA and Tukey multiple comparison tests were conducted to compare research team participants' engagement in the skills and practices of science outside the scope of the program over time. There was no significant increase in the amount of time that research team members thought about science-related questions and problems in non-program contexts (baseline vs. midpoint: p=0.421; midpoint vs. post: p=0.805; baseline vs. post: p=0.144).