



RESEARCH NOTE

REVISED Engaging high school students in neuroscience research -through an e-internship program [version 2; referees: 3 approved]

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Abstract

In this article, we describe the design and implementation of an e-internship program that BioScience Project offers high school students over the summer. Project topics are in the areas of behavioral neuroscience and brain disorders. All research, teaching, and communication is done online using open access databases and webtools, a learning management system, and Google apps. Students conduct all aspects of a research project from formulating a question to collecting and analyzing the data, to presenting their results in the form of a scientific poster. Results from a pilot study involving fifteen students indicate that students are capable of successfully completing such a project, and benefit both intellectually and professionally from participating in the e-internship program.



This article is included in the INCF gateway.

Open Peer Review

Referee Status:

	Invited Referees		
	1	2	3
version 2 published 29 Mar 2017			
version 1 published 09 Jan 2017	 report	 report	 report

- 1 **Christine F. Hohmann**, Morgan State University, USA
- 2 **Byron C. Jones**, University of Tennessee Health Science Center, USA
- 3 **Jennifer A. Ufnar**, Vanderbilt University, USA

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Comments (2)

Corresponding author: Anna Delprato (anna.delprato@gmail.com)

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REVISED Amendments from Version 1*Title*

Based on a suggestion made by an F1000 member we changed the title of the article to reflect the neuroscience research focus of the internship program.

Other major changes made to the manuscript are based on one reviewer's comments.

Abstract

A sentence was revised to clarify that student comprehension was not formally assessed in this pilot project.

We also specify the exact number of students that participated.

Introduction

We have added a paragraph to the introduction that highlights the benefits of a student/scientist association, internships, and e-learning. We have added four additional references in support.

Internship Implementation and Project design

We have included additional detail to explain the rationale and contents of the modules.

We have provided more information about the content discussed during and the frequency of the mentoring sessions.

Project design

The project design section has been moved and now appears after the Internship design section and before the database description.

See referee reports

Introduction

Neurogenomics is the study of the systems, networks, and gene interactions that underlie neural processes. Increased functional information from diverse sources available in open access databases, along with specific tools for analysis, enables the integration of these data to gain unique insights (Overall *et al.*, 2015). BioScience Project (www.bioscienceproject.org) offers high school students the opportunity to work as summer interns on research projects in the area of behavioral neuroscience and brain disorders, which includes the analysis of gene expression data using systems and network biology methods (see Schughart & Williams, 2017). This is a voluntary internship available to students regardless of academic performance or institution. Students participate in the program to gain hands on experience and acquire new skills. The projects involve learning how to formulate and test hypotheses, data-mine biological and neuroscience-specific databases, statistical analysis, and data representation and visualization. Students need only a computer with an Internet connection to participate. The projects are flexible, allowing students to work from home on their own schedule. All communication is done via the Internet with an online learning management system (Moodle, <https://moodle.com/>), Google apps (<https://gsuite.google.com/>), and video conferencing. At the end of the internship, students communicate their work in a poster, which can be used to leverage their college applications and/or detail their experience to prospective employers. Students also receive certificates of completion. Several strengths of the e-internship program worth noting are: (1) Students are highly interested in topics related to behavioral neuroscience and brain disease; (2) This is shown to be an

effective model to introduce early stage students to advanced topics and research methods in neuroscience; (3) Students receive the otherwise-limited opportunity to participate in authentic research projects and work directly with professional scientists; (4) The internship program is scalable, enabling many students to participate; (5) Project results are freely accessible to the scientific community on BioScience Project's website (www.bioscienceproject.org).

Science outreach programs that connect professional scientists to students and teachers such as "Scientist in the Classroom" (Laursen *et al.*, 2007), "Shadow a Scientist" (Clark *et al.*, 2016) and the "Virtual Scientist" (McCombs *et al.*, 2007) report enhanced student interest in science and an increase in the understanding of science concepts and relevance to real life. The experience also provides an awareness of ongoing research and current methods. Internships bridge theory and practice and are a useful way to supplement and enrich an individual's educational experience (Ruggiero & Boehm, 2016). The e-internship model extends this opportunity to a broader group of students.

Internship implementation Recruitment

Recruiting students is mainly done by contacting high school science departments through email and providing information about our organization and the internship opportunity. We include a recruitment poster (Supplementary File 1) and ask that the information be passed along to their students. We launched a two year pilot project that included both private and public institutions around the Boston (MA, USA) area. Schools were selected randomly. Several students from schools not contacted by us learned about the Internship program through word of mouth or an Internet search.

Internship design

The internship program runs for 6 to 8 weeks in July and August. Students may begin sooner if they like. The time commitment varies for each student, but is in the range of 10–15 hours per week. Students proceed at their own pace and can work alone or in a group. There are no deadlines, except to finish projects before the new school year begins. Project completion requires that students profile gene expression data associated with a brain disorder or behavior using a protocol designed by our laboratory and make a scientific-style poster of their work, which includes introduction, methods, results, and discussion sections.

Students are able to choose their topic of study or can select from subjects suggested by us. Project specific materials are provided throughout the internship. These include relevant literature for background information from science magazines (*Scientific American* and *The Scientist*), as well as links to news updates from sources such as EurekAlert! (<https://www.eurekalert.org/>), BBC Science (<http://www.bbc.co.uk/science>), Neuroscience News (<http://neurosciencenews.com/>) and YouTube (<https://www.youtube.com/>).

Students are provided with as much mentoring as they need to complete the internship. Mentoring sessions are done through video

conferencing and consist of a walk-through of each database with screen sharing, project discussion, and troubleshooting of problems. Mentoring sessions typically take place weekly and last anywhere from 30 to 90 min. Mentoring is requested and scheduled by email. All instruction and mentoring is provided by the project director, Dr. Anna Delprato. As the internship program grows, additional scientists will be recruited to assist with teaching. Students are not tested and there are no grades assigned. Teaching and communication is done through an online learning platform (Moodle; <https://moodle.com/>), one on one video conferencing (Skype or Google Hangouts), email, document sharing (Google Docs), and a Google group, which enables students to receive notices and communicate with one another. Google apps are also used for data handling (Google Sheets) and presentation (Google Slides). Students may also use Microsoft Office's Excel and PowerPoint software for the same purpose.

Project design

The protocol used for profiling gene expression data is broken down into steps so as not to overwhelm the students with too much information at once. Modules which consist of detailed instruction are built around each step of the protocol. The purpose of the module is to provide the students with a detailed reference in addition to the mentoring sessions so that they can work in the databases and with the data independently.

The starting point for all projects involves the identification of brain regions associated with a behavioral process or brain disease, which is based primarily on functional magnetic resonance imaging (fMRI) data. Students find this information through an Internet search with our assistance. Gene expression patterns are then analyzed to identify those genes that are preferentially expressed in these brain areas across all donor brains. For the genes identified in this way, clustering algorithms and gene ontology annotation are used to identify those entries that are directly related to the subject of interest. These genes are then used as hooks to build interaction networks in order to pull out additional functionally relevant genes.

All of the databases and analysis tools are open access. The core set of databases and web tools used in the internship are: The Allen Brain Atlas (gene expression data based on donor brains and correlation analysis; <http://brain-map.org/>), Venny (Venn diagram generator; <http://bioinfogp.cnb.csic.es/tools/venny/>), DAVID (Database for Annotation, Visualization and Integrated Discovery; functional annotation, pathway information, and clustering; <https://david.ncifcrf.gov/>; Huang *et al.*, 2009), PythonAnywhere (statistics, graphing; <https://www.pythonanywhere.com>) and STRING (network analysis; <http://string-db.org/>; Szklarczyk *et al.*, 2015). A more detailed description of these are provided in the following sections.

Allen Brain Atlas/Gene Expression

The Allen Brain Atlas combines genomic data with neuroanatomy through the generation of gene expression maps obtained from Affymetrix data (Hawrylycz *et al.*, 2012). The Allen Brain human database contains gene expression data for 6 donor brains. This

human database is queried using the differential search function, which enables a search to identify gene expression enrichment in one brain region as compared to another. For example, learning and memory are typically associated with the hippocampus, so in this case the differential search function is used to find genes that have enhanced expression in the hippocampus relative to other regions of the brain. Details on the usage of the differential search function can be found at the Allen Brain site (<http://help.brain-map.org/display/humanbrain/Microarray+Data#MicroarrayData-GeneSearch>). Students are taught how to interpret Affymetrix heatmaps, evaluate gene expression data (fold difference values, error, and threshold cutoff), and use spreadsheet editing, sorting, and graphing functions for the organization and analysis of large datasets.

The cleaned gene sets are then compared by the students to detect common and distinct elements using an online program (Venny) that evaluates lists and generates a Venn diagram as a visual representation. The genes that are common among all donors are then analyzed in DAVID for functional annotation, clustering, and pathway information. Genes that are associated with project relevant themes, such as behavior, nervous system development, and/or specific diseases, are used to build interaction networks, which consist of protein-protein interactions that are supported by multiple lines of evidence, such as experimental, text mining, and co-expression in the STRING database.

The interaction networks are used to identify potential gene candidates that may be involved in the same behavioral process or disease, and are also used to identify network substructures, such as hubs and motifs, which indicate important and possibly functionally related entities. Functional classification is assessed using DAVID to identify interactions that are relevant to the project topic. For an extended analysis, students can use the most pertinent genes extracted from the networks to identify additional candidates that have similar spatial expression profiles in the brain tissue of interest. The correlation analysis is done in the Allen Brain database using the correlation search function (<http://help.brain-map.org/display/humanbrain/Microarray+Data#MicroarrayData-CorrelativeSearch>).

Finally, a statistical analysis of the gene expression data is performed by the students with Python, using an online Python server, PythonAnywhere, which enables students to run Python scripts from their browser. Students are provided with a general script and are required to modify this for their own datasets. The script returns general statistics, such as standard error, mean, minimum and maximum, variance, and distribution profiles.

Internship outcomes

The internship program has run for two years since 2015. The first year, five students participated and in the second year ten students participated. Student project topics included addiction, learning and memory, Alzheimer's disease, creativity, and bipolar disorder, among others. Student posters can be viewed at the BioScience Project website (<http://www.bioscienceproject.org/student-posters>). This year a student also coauthored a published research article with our group, which reports on the identification

of genetic factors associated with morphine addiction (Crusio *et al.*, 2016). Upon completion of the internship, students answered survey questions pertaining to the internship content, instruction, and overall experience. The student responses to the survey questions are presented in Table 1 and Table 2. Comments and suggestions provided by the students can be viewed in Supplementary File 2. Based on the student feedback in 2015, the internship instruction was revised for clarity using step-by-step annotated screenshots together with one-on-one tutorials via video conferencing for each database and method.

Conclusions

This e-internship program has been shown to be a useful way of introducing early stage students to advanced topics and research methods in systems biology, which supplements their high school science curriculum and provides them with an opportunity to gain hands on experience. Students are interested in collaborating with scientists on research projects in neuroscience-related topics and they gain both intellectually and professionally from participating in the summer e-internship program. Given the flexibility in both time and procedure, this

Table 1. Neuroinformatics Internship Student Survey 2015.

Survey Questions	Responses		
	Yes	No	Other
1. Was the internship content clearly presented?	4	1	
2. Was the internship content interesting?	5		
3. Could you navigate the module easily?	4		1*
4. Did you acquire new skills and knowledge?	5		
5. Would you recommend this internship to others?	5		
	Excellent	Good	Satisfactory
6. What overall rating would you give this internship?	2	2	1
7. What overall rating would you give the instructor?	4	1	

*"It was a bit confusing in the very beginning, but after a bit of experience it became very easy to use."

Table 2. Neuroinformatics Internship Student Survey 2016.

Survey Questions	Responses		
	Yes	No	Other
1. Was the internship content clearly presented?	8	2*	
2. Was the internship content interesting?	10		
3. Could you navigate the module easily?	10		
4. Did you acquire new skills and knowledge?	10		
5. Would you recommend this internship to others?	10		
	Excellent	Good	Satisfactory
6. What overall rating would you give this internship?	4	5	1
7. What overall rating would you give the instructor?	10		

* Comment1: "It varied from step to step, sometimes it was clear and sometimes I was a little confused." Comment2: "The steps were clearly presented and we had a lot of help through the ones we didn't understand, but the overarching goal/conceptual understanding of the project was a bit confusing during the steps."

e-internship program can easily be extended to include more students.

technology and outreach. AD and WEC wrote the manuscript. All authors read and approved the final manuscript.

Author contributions

AD designed and implemented the project. WEC contributed expertise in neuroscience and CR contributed expertise in educational

Competing interests

No competing interests were disclosed.

Grant information

The author(s) declared that no grants were involved in supporting this work.

Supplementary material

Supplementary File 1: Internship recruitment poster.

[Click here to access the data.](#)

Supplementary File 2: Student feedback.

[Click here to access the data.](#)

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Open Peer Review

Current Referee Status:   

Version 2

Referee Report 18 April 2017

doi:[10.5256/f1000research.12180.r21901](https://doi.org/10.5256/f1000research.12180.r21901)



Jennifer A. Ufnar

Department of Teaching and Learning, Vanderbilt University, Nashville, TN, USA

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Referee Report 20 February 2017

doi:[10.5256/f1000research.11391.r19554](https://doi.org/10.5256/f1000research.11391.r19554)



Jennifer A. Ufnar

Department of Teaching and Learning, Vanderbilt University, Nashville, TN, USA

The article by Anna Delprato describes an interesting way to engage students in an online research program in the neurosciences. This reviewer is interested in the program and the potential impacts and uses of the program for K-12 students. This reviewer, however, has several concerns that need to be addressed before the paper is indexed.

1. The authors stipulate in the abstract that the students in the program were "capable of comprehending ...such a project". The authors cannot make that claim with the evidence presented in the manuscript. Self-reported surveys were the only form of data presented, and this type of survey does not show student learning or comprehension. The reader also does not know if this comprehension is applied to the ability to perform research, the content learned, or learning how to communicate the information (or a combination of all three). This is a significant concern and must be addressed before publication.
2. There were only six references cited for the entire manuscript. There are many papers in the literature that discuss programs similar in nature to this. It would behoove the authors to include more background research to support their claims.

3. The authors need to include more information about the project itself (i.e. a discussion of the modules used for teaching, the mentoring, etc.). The reader is left wondering if the students are doing actually self-initiated projects, or if they are being led by the modules. It was helpful to read about the databases that the students use, but the reader does not gain any knowledge about the actual e-internship program through which the students progress (or are those the modules? It is unclear.). In other words, how were they mentored? Is the mentoring effective for student growth? How are the modules designed? Is there any research to show that the module design is effective? Do they present and defend their research in a scientific forum (even online)? It would also help to put the Project Design section first (before the database discussion).
4. The evaluation of the program needs to be more robust. Self-reported surveys are a good starting point, but they are only formative assessments. You need to include some summative assessments for the program and more qualitative assessments to determine the efficacy of the program for student learning. Also, it sounds as though the students are spending much less time on the project as opposed to an onsite laboratory model, so the reader is left wondering if the program is really effective. Also, do you have demographics of the participating students?
5. There are a couple of grammatical errors (mostly words that need to be omitted and comma usage errors).

In summary, this manuscript presents an interesting program, but the authors need to address the issues of a clear evaluation plan to determine the efficacy of the program, and provide enough discussion of the program so that readers understand exactly what the students gain.

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 26 Mar 2017

Anna Delprato, BioScience Project, Wakefield, USA

We thank the reviewer for the insightful comments and suggestions. Below we respond to each point of the review. We have submitted an updated version of the article that incorporates the requested changes and provides additional information about the internship program.

Reviewer's comment

1) The authors stipulate in the abstract that the students in the program were "capable of comprehending ...such a project". The authors cannot make that claim with the evidence presented in the manuscript. Self-reported surveys were the only form of data presented, and this type of survey does not show student learning or comprehension. The reader also does not know if this comprehension is applied to the ability to perform research, the content learned, or learning how to communicate the information (or a combination of all three). This is a significant concern and must be addressed before publication.

Author's response

We have removed the statement that students comprehended the internship project from the abstract as this was not formally evaluated in the pilot study.

Reviewer's comment

2) There were only six references cited for the entire manuscript. There are many papers in the literature that discuss programs similar in nature to this. It would behoove the authors to include more background research to support their claims.

Author's response

We have provided additional references as requested. If the reviewer is aware of other relevant references, we will include them in the article.

Reviewer's comment

3) The authors need to include more information about the project itself (i.e. a discussion of the modules used for teaching, the mentoring, etc.). The reader is left wondering if the students are doing actually self-initiated projects, or if they are being led by the modules. It was helpful to read about the databases that the students use, but the reader does not gain any knowledge about the actual e-internship program through which the students progress (or are those the modules? It is unclear.) How are the modules designed? Is there any research to show that the module design is effective?

Author's response

The modules are based on a protocol that was designed in our laboratory for profiling gene expression data to identify genes of interest associated with a behavior or brain disorder. The protocol is broken down into steps so as not to overwhelm the students with too much information at once. Modules which consist of detailed instruction are built around each step of the protocol. The purpose of the module is to provide students with a detailed reference in addition to the mentoring sessions so that they can work in the databases and with the data independently. The effectiveness of the modules has not been formally evaluated. We would like to also provide the students with screen casting videos for improved instruction. We hope to make the videos available to students this season.

Reviewer's comment

4) In other words, how were they mentored? Is the mentoring effective for student growth?

Author's response

Student mentoring primarily occurs through video conferencing and includes a walk-through of each database using screen sharing, project/topic discussion, and troubleshooting. Mentoring sessions occur weekly and last anywhere from 30 min - 90 min. Students also email us with questions.

The effectiveness of the mentoring sessions on student growth has not been assessed formally but we believe that mentoring is necessary for the students to perform their research and complete their projects.

Reviewer's comment

5) Do they present and defend their research in a scientific forum (even online)?

Author's response

Students have not presented and/or defended their research in a scientific forum, but this is a great idea and we will add it to this year's program.

Reviewer's comment

6) *It would also help to put the Project Design section first (before the database discussion).*

Author's response

Done

Reviewer's comment

7) *The evaluation of the program needs to be more robust. Self-reported surveys are a good starting point, but they are only formative assessments. You need to include some summative assessments for the program and more qualitative assessments to determine the efficacy of the program for student learning.*

Also, it sounds as though the students are spending much less time on the project as opposed to an onsite laboratory model, so the reader is left wondering if the program is really effective.

Author's response

The internship described in this study constitutes a dry lab experience. All of the research and analysis is done on a computer. Performing this type of work for 6 to 8 hours per day is physically and mentally taxing and can result in errors. We recommend that students spend about 10 to 15 hours per week working on their projects. The nature of bioinformatics-based research is very different from a classical wet lab experience which entails physical manipulations at the bench. We believe that both types of research internships are valuable to students but program efficacy cannot be evaluated based solely on time spent given the differences between the two approaches.

Reviewer's comment

8) *Also, do you have demographics of the participating students?*

Author's response

We ask students to provide us with their resume in order to get an idea of their science background but we do not collect demographic information.

Reviewer's comment

9) *There are a couple of grammatical errors (mostly words that need to be omitted and comma usage errors).*

Author's response

Corrected

Reviewer's comment

10) In summary, this manuscript presents an interesting program, but the authors need to address the issues of a clear evaluation plan to determine the efficacy of the program, and provide enough discussion of the program so that readers understand exactly what the students gain.

Competing Interests: The authors have no competing interests.

Referee Report 08 February 2017

doi:10.5256/f1000research.11391.r19553



Byron C. Jones

Department of Genetics, Genomics, and Informatics, University of Tennessee Health Science Center, Memphis, TN, USA

The description of the internship program is clear and convincing. One minor issue is with Table 2 -- the ** is missing from the body of the table.

Are there plans to obtain financial support for the students?

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 21 Feb 2017

Anna Delprato, BioScience Project, Wakefield, USA

Thank you for reviewing our article. We are seeking funding for student support and program expansion.

Competing Interests: No competing interests were disclosed.

Referee Report 08 February 2017

doi:10.5256/f1000research.11391.r19850



Christine F. Hohmann

Department of Biology and RISE Program, Morgan State University, Baltimore, MD, USA

The paper by Crusio, Rubino and Delprato, appropriately titled: “**Engaging high school students in systems biology through an e-internship program**”, provides a description of a research education program at the high school level. The authors have developed an online research training program that uses public access genomics and neuroscience data bases to train students in behavioral neurogenetics. Students exercise a substantial amount of autonomy (“are able to choose their own projects”, “proceed at their own pace”). Students were mentored through the process of identifying their projects, conducting

their research and preparing a capstone poster presentation by the co-author, Dr. Anna Delprato. According to the website for the program, all students who participated in the project successfully submitted their capstone posters which appear to be of a very sophisticated nature. One student even accomplished to co-author a research paper with the first author of this paper. Unfortunately, the viewing option online (at least for this reviewer and her mac computer; maybe I need tech help??) made it impossible to read the *details* of the posters and after download, the image quality was insufficient, when enlarged, to see much. Survey data indicate that the participants were, with few exceptions in year 1, very satisfied with this learning opportunity which had two iterations so far.

This online training/mentoring model offers a very exciting possibility for (global) distance learning. It is currently based on a very small students sample (5 year one and 10 in year 2) from just a couple of high schools located in New England and on limited assessment. It would have been helpful to know the demographics of the student population involved as well as the graduation rates at this school and how many graduates typically attend college. It would also be helpful to know how many hours, on average, Dr. Delprato spend with each student/student group over the course of the summer. I hope that, as the authors continue their model, they will follow their participants' future educational and career decisions to assess the impact of the training experience. There is a lot of potential in this model to be implemented within the context of course based research, at the college level as well as for integration into federally funded existing training programs in the US. I would like to encourage the authors to prepare a publication on the specifics of their curriculum in near future, if they are interested in having others adopt this model and implement it in different settings.

In conclusion, although this is a very preliminary and descriptive account of a summer research training experience its novelty merits publication even at this early stage. The paper provides sufficient detail to engender ideas for others to attempt to replicate the model, although a more detailed description of the curriculum, and follow up analysis with a larger data set, should be encouraged.

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 21 Feb 2017

Anna Delprato, BioScience Project, Wakefield, USA

Thank you for reviewing our article. We have changed the file format of the students posters to pdf. This has improved the resolution for online viewing.

Competing Interests: No competing interests were disclosed.

Discuss this Article

Version 1

Author Response 22 Feb 2017

Anna Delprato, BioScience Project, Wakefield, USA

Thank you for your suggestion. We will consider changing the title in the revised version of the article.

Competing Interests: No competing interests were disclosed.

Reader Comment (*Member of the F1000 Faculty*) 22 Feb 2017

Peter Uetz, Center for the Study of Biological Complexity, Virginia Commonwealth University, USA

I suggest to change "systems biology" in the title to something like "brain systems biology" or the like, to be more precise.

Competing Interests: None

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