Authentic Undergraduate Research in Machine Learning with The Informatics Skunkworks: A Strategy for Scalable Apprenticeship Applied to Materials Informatics Research

abstract

The Informatics Skunkworks program provides a new framework for engaging undergraduates in research experiences, with a focus on the interface of data science and materials science. The program seeks to provide authentic research, engaged personal learning, and professional development while also being efficient, accessible, and scalable. Initially developed at the University of Wisconsin-Madison, participation continues to grow, with over 90 students engaged in research or training activities during the Fall 2021 semester from 4 institutions. The Skunkworks focuses on reducing barriers to engagement for mentors and students in undergraduate research by replacing bespoke and ad-hoc approaches with efforts and infrastructure that are reusable and scalable, including simplified standardized recruiting methods, online modular training resources, flexible undergraduate accessible software tools, long-term research projects with many similar but distinct components to engage large teams, and support from a learning community. For example, new students have the option to participate in a modular, self-paced, online onboarding curriculum that teaches students the basic skills needed for most data science projects, thereby dramatically reducing the mentor time needed to engage students with limited background in machine learning research. Projects are authentic research challenges that strive to allow for large flexible teams, thereby scaling up their impact from the typical engagement of just one or two students and allowing for extensive peer teaching. Throughout the program, professional development activities are efficiently delivered through standardized materials to teach critical research skills like record keeping, establishing group expectations and dynamics, and networking. These skills are also reinforced at workshop events hosted during the semester, which are effectively delivered online and yield growing impact for modest effort as the community grows. The program has been successfully implemented as evidenced by the last two semesters' evaluation findings through interviews, focus groups, and pre-post surveys. The students reported a positive attitude towards the program. Students' perception about machine learning knowledge and skills and their self-confidence improved after they got involved in the program. The instructors and mentors indicated positive teaching and mentoring experiences, and shared ideas on the further improvement of the program. Building on its early successes the team is continuing to implement evaluation data-driven improvements to the program with the goal of continuing to grow through new collaborations.

introduction

Mentored undergraduate research experiences where students are given a hands-on opportunity to engage in research are known to provide positive outcomes for both the mentor and mentee [1], [2]. Typical structures include paired research mentoring and course-based research. Paired research between a faculty and undergraduate student where the student participates as part of the faculty's research group is perhaps the most direct approach which maximizes the amount of mentee-mentor interaction [3]. These mentor-mentee dyads occur regularly on campuses of all sizes and types during the academic year and are also associated with summer undergraduate research programs (e.g. National Science Foundation supported Research Experiences for

Undergraduates). Course-based approaches may rely on pairing individual students with mentors while providing a structure for the research experience [4] or have an entire class of students address a research question as a group [5].

While the structures of these authentic research experiences vary, they carry higher benefits for the mentees when they include extended involvement over time, require higher level research engagement (with data analysis, question posing, and hypothesis development), and provide instructional supports [6]. The importance of embedding research professional development skills is also key to maximizing the positive impacts of such experiences on the undergraduate mentees involved [7]. Professional development training on topics related to the context of research has been shown to reduce barriers to research involvement and improve confidence in a student mentee's ability to make contributions to a research team [8].
The Informatics Skunkworks program seeks to enable research mentors to engage more students in undergraduate research on the topic of materials informatics, while still maintaining much of the structure of a traditional paired research approach. To do this the Skunkworks team has pursued two parallel tasks. The first is to ***develop resources*** to lower the barrier to initiating and maintaining undergraduate research efforts for the mentor themselves. This includes development of streamlined recruiting, educational onboarding materials, and software tools that support common research tasks. The second task has been to ***develop a community of practice*** to enable a network of mentor/mentee teams to productively engage with each other, collaboratively use and continue to develop the above resources, and sustainably grow the Informatics Skunkworks program within and across institutions.

The Informatics Skunkworks group was formed in Fall of 2015 with three mentors and 15 students with initial growth largely driven by continued student and mentor interest. As the group grew more structured assessment of the program has become a larger focus to understand what is working well, where improvements can be made, and how continued growth of the program can succeed. In this paper, we focus on the Informatics Skunkworks program development process, program implementation and its outcomes during Fall 2021 semester. During this semester the Skunkworks ran 17 research projects with 10 mentors and was able to engage 57 students in undergraduate research experiences, and 38 students in an educational onboarding course referred to later as the "education group". These activities for students across four institutions with research efforts being led from University of Wisconsin-Madison (UW) and Boise State University (BSU).

skunkworks program structure for fall 2021

Student Enrollment: Before the Fall 2021 semester recruitment of student participants was promoted via an active list of available projects maintained on the Skunkworks website (https://skunkworks.engr.wisc.edu/), recruitment emails sent out to undergraduate students in the college of engineering and computer science, and remote information sessions held during the first week of the semester. Interested students with sufficient background were then assigned research groups based on their interest and background. Students with little or no background were encouraged to participate in an onboarding "education group" led by a mentor from the Skunkworks team. The education group is separate from the research groups and students generally participate for a semester in the education group prior to joining a research group. Occasionally students participating in the education group may attend a few research group

meetings to observe and facilitate future transitions to participating in a research group. Students participating in either type of group were encouraged to register for credit in "independent study" type courses where available with a recommended commitment of around 10 hours a week.

Skunkworks Research Groups: Skunkworks research groups were typically structured with 1 research mentor (graduate student, faculty, postdoc) leading a group of 4-6 undergraduate researchers. Mentors were free to adjust the group interactions, but it was suggested that teams meet synchronously once a week for a weekly research meeting. During this meeting teams discuss research progress, assign weekly tasks, and answer any questions that came up during the previous week. Outside of these synchronous meetings groups were encouraged to interact asynchronously via a group Slack channel on the Skunkworks Slack workspace. To facilitate productive weekly research meetings students are required to construct a Weekly Slide Deck which summarizes their work over the past week. Students were provided with a template for these slide decks in order to promote inclusion of key information to improve the effectiveness of the weekly meetings. Finally, at the end of the semester students were asked to construct a final slide deck which summarized their progress and results throughout the semester. Note that the adoption of some level of standardization about mentoring approaches helped mentors by reducing preparation time and supporting quick adoption of best practices. Such standardization, rarely pursued in undergraduate research experiences, is a key aspect of making the Skunkworks more scalable.

Skunkworks Education Group: This group has the goal of teaching basic concepts and tools that many of the research teams use and serves to provide a smoother entry point for both the students and for project mentors. Students are encouraged to transition from the education group onto research projects at the end of the semester. The Skunkworks education group was structured with 1 instructor and accommodates a flexible number of students depending on interest. The meeting structure was set up to mirror that of the research groups with 1 weekly meeting required of participants with assigned weekly activities to be completed and submitted at the following meeting. Three meeting times were offered to accommodate student schedules and were hosted remotely through Zoom. The curriculum consisted of a set of modular educational materials which are described in detail in the Skunkworks Resources section of this paper.

Weekly activities fall broadly into three categories: introductions to machine learning concepts, introductions to research tools, and research professional development. Several professional development topics have been identified as particularly relevant to Skunkworks' projects, and include professional communication, building networks, working with a diverse team, and project management [9]. To show completion of each activity education group students also construct a weekly slide deck which summarizes the results of each activity. The structure of these slide decks is defined in a template given to the students, and completion is assessed through review of select "assessment figures" that are defined for each activity.

Skunkworks Workshops: In addition to the activities for each group of students discussed above, three Skunkworks community wide workshop events were hosted in the Fall 2021 semester. The first was a Workshop on Responsible Conduct in Machine Learning Research. The Second was a workshop on Science Communication with the core activity being the development of an "elevator pitch" of their research. The final event was an end of semester meeting referred to as the "All-hands Meeting" during which there was a presentation from an industry collaborator on "A Day

in the Life of a Data Scientist" from Citrine Informatics along with research presentations by select Skunkworks research groups.

skunkworks resources for fall 2021

During the Fall 2021 semester three types of resources were developed and used for this program.

Skunkworks Slack Workspace: A Skunkworks Slack workspace was maintained throughout the Fall 2021 semester with channels dedicated to individual groups within the Skunkworks (research groups and education group). Research mentors were encouraged to use Slack as the primary means of group communication though it was not a strict requirement. Several community wide channels were also setup to facilitate communication to the Skunkworks participants overall including a #general channel where community events and announcements took place as well as a specific #opportunities channel where posts related internships, grants, fellowships, or other resources that might support student participation were posted.

Materials Simulation Toolkit for Machine Learning: The MAterials Simulation Toolkit for Machine Learning (MAST-ML) is a machine learning workflow package written in python that continued to be refined during the Fall 2021 semester [3]. This software package was originally generated from a set of scripts past participants developed to standardize their research workflows and was developed into a package used by a number of the Skunkworks groups to accelerate their research. This tool was introduced in the educational onboarding course and standardizes many common workflows that the Skunkworks research projects use. This allows students to spend more time answering questions related to their research and less time wasted in small technical mistakes.

Educational modules: A set of educational modules was updated for the Fall 2021 semester based on prior semester and summer interactions with other groups of undergraduate students. These modules formed the core curriculum for the Skunkworks Education Group and can also be used to fill in gaps in knowledge for students joining Skunkworks research groups. There are five modules related to introducing machine learning concepts and tools. These modules are Basics of Machine Learning, Introduction to Citrination, Introduction to MAST-ML, Modifying Machine Learning Workflows with MAST-ML, and Optimizing Model Predictive Ability via Hyperparameter Optimization. These modules include readings, videos, and PowerPoint slides which introduce the concepts or tools. They then include instructions for a hands-on activity which walks through the tools and concepts. These activities make heavy use of cloud computing resources Google Colab, Nanohub, and Citrination which allow students to run and execute software without having to install and run on a local computer. Each module is expected to take 6 hours to complete between the activity and associated introductory material.

methods for skunkworks program assessment Fall 2021

Data Collection and Program Evaluation: To develop a comprehensive understanding of the Skunkworks program and to conduct a thorough evaluation, we gathered data through qualitative and quantitative methods from project mentors and student participants. The data from multiple sources complemented each other and improved both reliability and validity of the findings and

increased the credibility of the overall evaluation. Assessments were led and analyzed by an independent evaluator who used statistical software (SPSS) to analyze the quantitative data. Content-analysis and coding of the qualitative data was conducted to summarize themes from the qualitative data.

measurements

Two surveys were conducted on Skunkworks student participants, a pre and post survey. The survey consisted of both close-ended and open-ended questions.

Close-ended Questions: On the pre and post surveys, students were asked to report their knowledge, skills and satisfaction level on six key areas: Machine Learning knowledge, Machine Learning (ML) Skills, General Research Skills, Research Confidence, Satisfaction with Group, Satisfaction with Instructional Materials , and Satisfaction with Research Mentorship on s 5-point Likert scales (1~5, 1 being the lowest and 5 being the highest). The complete survey items are included in the appendix.

Table 1. Measurement Scales

Scale (Category)	# of Items	Scale
ML Knowledge (Information)	11	1~5: 1= Not at all informed, 5= Very informed
ML Skill	8	1~5, 1 = Not Skillful at all, 5= Very Skillful
Overall/General Skill	14	1~5, 1 = Not Skillful at all, 5= Very Skillful
Confidence	7	1~5, 1= Not Confident at all, 5=Very Confident
Satisfaction with Students	5	1~5, 1=Very Dissatisfied, 5= Very Satisfied
Satisfaction with Instructional Materials	5	1~5, 1=Very Dissatisfied, 5= Very Satisfied
Satisfaction with Research Mentorship	7	1~5, 1=Very Dissatisfied, 5= Very Satisfied

Open-ended Questions*:* To acquire a deep understanding of the students' perception and feedback there were three open-ended questions where students reported on (i) the Skunkworks elements they liked most, (ii) what additional content they would like to have in the program (iii) additional feedback about the program.

mentors' perception of the skunkworks program

To learn about mentors' perceptions and experience of Skunkworks program, a guided discussion was hosted 1 week after the end of the Fall semester's activities. In this meeting, the mentors discussed: i) how they felt about the program, ii) while mentoring/teaching Skunkworks program what worked and what challenges they faced, and iii) what in Skunkworks did they think needs

improvement. During the mentor focus group an external evaluator observed and guided the discussion. This discussion was also recorded for later analysis.

skunkworks program fall 2021 outcomes

Participants: For the Fall 2021 semester there were 10 research project mentors leading a total of 17 research projects. Of the total projects 14 were led from the University of Wisconsin–Madison, and 3 were led from Boise State University. 57 students participated in Skunkworks Research projects giving an average group size of 5.7 students per mentor. 38 students participated in the education group with students participating from Boise State University (4), Texas A&M University (4), and the University of Wisconsin–Madison (30).

Historical Participation: In addition to participation during the Fall 2021 semester students have been participating in the Informatics Skunkworks since its inception in Fall 2015 (15 students, 3 mentors). Participation steadily rose to 51 student researchers in Fall 2019 before dropping significantly due to COVID with 27 student researchers in Fall 2020. However, student participation rapidly recovered with 54 student researchers in Spring 2021. The first semester for the education group was Fall 2017 with 10 students participating. This number stayed steady ranging between 5-15 students until Spring 2021 when participation expanded rapidly to 37 students. Among the students who participated in the education group, on average 49.6 percent of students continue on to participate in at least one semester of research with a Skunkworks research group.

Research output: One of the core themes of the Informatics Skunkworks program is participation in authentic research. Ideally this means projects that lead to publishable results that expose students to the process of writing and publishing papers. The Skunkworks group currently has 7 journal papers published and one under review [10]–[16].

findings from student surveys

We conducted two surveys among the Fall 2021 Skunkworks students. A pre-survey for all student participants was distributed during the first week of research meetings and education group meetings. Then, at the end of the semester a corresponding post-survey was distributed during the final week of organized meetings. In the Fall 2021, out of the 95 Skunkworks students, 48 students responded to the pre-survey and 15 students responded to the post survey. Independent sample t-tests were used to analyze the difference between the pre and post scores of students' perception of their involvement in the Skunkworks program.

Table 2. Students Perception of Participation in the Skunkworks Program

Category	Pre (n)	Pre Mean (M)	Standard Deviation (SD)	Post (n)	Post Mean (M)	Standard Deviation (SD)	p	t
*ML Knowledge	25	2.25	.966	6	4.05	.687	<.001	-4.279
ML Skill	48	2.56	1.08	13	3.78	.648	<.001	-3.882

General Research Skill	48	3.59	.743	13	3.85	.845	.281	-1.088
Research Confidence	47	3.66	.961	13	3.80	.784	.628	-0.487
Satisfaction with Students/Team	-	-	-	13	4.39	.705	-	-
*Satisfaction with Instructional Materials	-	-	-	5	4.92	.110	-	-
Satisfaction with Research Mentorship	-	-	-	12	4.58	.687	-	-

*Only Education Group students were asked to respond to 'ML Knowledge' and 'Satisfaction with Instructional Materials' scales.

Students ML Knowledge, ML Skills, Overall Skills and Confidence: As seen in Table 2, on average students reported significantly higher 'ML Knowledge' and 'ML Skills' in the post-survey as compared to the pre-survey. Students also reported higher levels of 'General Research skills' and 'Research confidence', in the post survey as compared to pre survey (though not statistically significant).

Students' Satisfaction with fellow Students/Groups, Instructional Materials and Research Mentorship: Students were also asked to report their satisfaction on three areas: Satisfaction with Students in Team/Group, Satisfaction with Instructional Materials/Group/Team-Mentor/Lead, and 'Satisfaction with research mentorship'. Due to timing of the pre-survey during the first week of participation, these are only reported for the post-survey. In all three areas, students reported high satisfaction with average values ranging between 4.39 and 4.92 on the 5 point scale.

findings from open-ended feedback

Several open-ended questions were asked in the pre and post surveys. Students were asked to report their most liked elements of the Skunkworks program, their expectations from the Skunkworks program that were not included in their experience, and any additional general feedback.

Most liked elements of Skunkworks program by the students (n=6): The most liked features of Skunkworks program are the instructional materials which included weekly homework using Google Colab notebooks. They specifically appreciated developing a clear purpose to work towards while having existing ML workflows to learn different ML techniques. Students in the research groups commented on the opportunity to apply the information they learn, and the opportunity to work directly with a research mentor specifically to get feedback about their progress.

Students expectations that were missing in the program (n=6): Students reported that they had expected more information and training on various issues related to material science research, and more in-person interaction with Skunkworks mentors and students. As the COVID pandemic continued to evolve and the majority of communication continued to be virtual, students' strong desire for more in-person communication was heightened.

Students' feedback about Skunkworks program (n=5): Students reported they were excited about the program, and they look forward to continuing to have a positive experience in the program. However, there was limited specific feedback.

findings from mentors' focus group

Nine mentors joined the focus group meeting and shared their thoughts. The evaluator recorded the meeting and took notes throughout the discussion. For each question in the focus group key themes were identified.

Motivating factors for mentors to join the program: Mentors reported many factors that worked as motivators to join the program. The most mentioned reasons were: (i) to gain mentoring experience, (ii) to get familiarized with new and hands-on way of learning while mentoring, (iii) to build their professional network, and (iv) to engage in a program that aligns with their current job and research responsibilities.

Mentors' impression of the Skunkworks program: Mentors expressed good impressions about the program. The mentors believe the program is a great platform for the undergraduate students to gain research experience, an opportunity for network building, and an experience involving learning and publishing in groups. Mentors found that the program positively influenced their undergraduate students to stay in STEM majors. They also believed it to be a great platform for graduate students and the early career faculty members to gain mentoring experience.

Strengths of the Skunkworks program from mentors' perspective*:* While discussing the strengths of the program the mentors identified the instructional materials as being very well developed. They noted the open and easy access to instructional materials through the Cloud as being beneficial for students and mentors.

Program challenges reported and recommendations offered by mentors: Mentors discussed the challenges they faced while implementing the program and also offered some recommendations for improvement. One main challenge reported by the program mentors was among some highly motivated students who took the program/ course as 'non-credit' / voluntary program. These students found it hard to balance their effort and program expectation as they prioritized their 'for credit' courses over Skunkworks and thus they could not spend enough time to effectively participate this program. Mentors also discussed some curriculum issues in need of minor revisions and additions. One other area that mentors indicated as a challenge was the lack of students' communication outside of regularly scheduled meetings. Mentors recommended ensuring more effective and frequent student-to-student and student-to-mentor communication through Slack or other mechanisms.

discussion and take-aways from fall 2021 assessment

The evaluation findings of the students' surveys and mentors' focus group observation data suggest that Skunkworks has been successfully implemented as evidenced by the positive attitudes of the students and the mentors discussed above. Moreover, the successful implementation of the program by different institutions indicates the program's transferability and potential for increased engagement and the future sustainability. However, some challenges were revealed that could be addressed to enhance both the student and mentor experience.

The largely positive responses from students suggest that gains in machine learning knowledge and machine learning research skills as a strength of Skunkworks. However, it is worth noting that the large discrepancy in response rate between the pre and post survey may have skewed these results. It is possible that students who had the motivation to respond to the post survey were also generally more motivated and higher achieving overall. Therefore, it may be possible that perceived improvements are an artifact of a bias in student responses. To mitigate the difficulty in obtaining correlated pre-post survey data in the future, we plan to implement a modified version of the existing survey in the Spring 2022 semester in which one survey is given at the end of the semester and students are asked to retrospectively respond with questions related to their experience at the beginning. This survey will be distributed and completed during the end of semester "all-hands" meeting which all students are expected to attend.

Unexpectedly, students' reported gains in general research skills and confidence did not match those of the ML specific gains. Specifically, they did not report any significant gains in this subset of questions. The cause of this is unknown, but the result highlights a concern that they are either not picking up these skills or not recognizing how the skills that they are learning tie into the larger research context. One factor that may contribute to this difference in reported gains is that the ML-specific skills asked about in the survey were much more concrete and therefore may be easier to recognize. These skills are also directly tied to the individual daily and weekly tasks the students completed. On the other hands research skills questions asked were more broadly framed or longer term in nature, so it may be harder for students to recognize key things they did over the course of the semester that would build those skills.

One highlighted concern from the mentor focus group was maintaining student engagement throughout the semester. This concern may also be mirrored in the declining student survey response rate discussed previously. Several mentors had a poor experience with students deciding to end participation part-way through the semester or having a significant drop in productivity. Part of this might be tied into the remote nature of participation for the Fall 2021 semester due to the continuing COVID pandemic. This was mirrored in the open-ended responses from students where a strong desire for in-person participation was expressed. While we cannot commit to a transition back to in-person meetings for all of those engaged in Skunkworks moving forward, we will strive to keep this as a high priority for future participation as much as possible.

Tying into these themes of student engagement with the program overall was also a theme of student engagement with each other, both within research groups and within the Skunkworks overall. To address student engagement with each other outside of once-a-week team research meetings, mentors are being encouraged to also set up a dedicated synchronous work time (either

remote or in person depending on comfort level) for just the student participants. The goal is to have at least one additional time in students' calendars where they are expected to meet and interact outside of their weekly research meetings with their mentor.

One final take-away has been related to the focus of materials and resource development within the Skunkworks. While the focus on previous development has largely been on improving the undergraduate experience via educational onboarding materials and software to enable student researchers to work more efficiently, we also plan to add additional support for new and continuing project mentors in the form of a mentor guide with suggested structure for running projects, research mentor training led by the Skunkworks team, and additional development of the mentoring community.

We believe innovation in teaching, learning, and research is a process and needs continuous improvement. By working on the challenges identified and following the recommendations from the evaluation data described above, we plan to refine and continuously improve the program to ensure more successful implementation and sustainability of the program in the future.

conclusions

The Informatics Skunkworks research program demonstrates that it is possible to expand the impact of valuable undergraduate research experiences by enabling research mentors to engage with multiple undergraduate researchers instead of a traditional one on one mentoring structure. This is further enabled and supported by the development of tools that support common research workflows, educational materials and structure that supports the onboarding of new students, and the development of a community of practice that continues to grow with additional student interest. The overall outcome of roughly 50% of students continuing to participate in at least one semester of research with a Skunkworks research group beyond the first semester of Skunkworks education engagement is highly promising. Based on these outcomes the Skunkworks team is engaged in continuous improvement of the program and expansion to new mentors, new students, while also improving the experience of those already involved. Student interest in joining the program continues to expand semester by semester and we are working to continue to meet those demands.

acknowledgements

This material is based upon work supported by the National Science Foundation under grant OAC 2017072. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

appendix:
Student pre-post survey

Students' Fall 2021 Survey Items

Student's first Name:
Student's Last Name:

Which university are you participating from?

- University of Wisconsin-Madison
- Boise State University
- University of Puerto Rico, Mayaguez
- Brigham Young University
- Others (Please mention)……

Please list at least 3 goals you hope to achieve by participating in Skunkworks.

_____

Which Skunkworks stage you currently in?

- Education Group
- Research project

Machine Learning Knowledge/ Information (ML Knowledge/ Information): How informed do you consider yourself to be about?
(This question is for Education Group Only):
(1= Not at all informed, 2= Slightly informed, 3= Somewhat informed, 4= Fairly Informed, 5= Very informed. N/A= Not Applicable)

	1	2	3	4	5	N/A
what machine learning is?						
how machine learning can be used to answer a research question?						
evaluating whether a data set is suitable for machine learning?						
cleaning data sets for machine learning?						
using elemental properties as features in machine learning?						
engineering features in a data set prior to creating a model?						
training and testing a machine learning model?						
decision tree based machine learning models?						
evaluating the performance of a model?						
steps to optimize models?						
the types of predictions a given model is suited to making?						

Machine Learning Skills (ML Skills): How skillful do you consider yourself to be at:
(1= Not at all skillful, 2= Slightly skillful, 3= Somewhat skillful, 4= Fairly skillful, 5= Very skillful. N/A= Not Applicable)

	1	2	3	4	5	N/A
recognizing whether or not machine learning can be used to answer a particular research question?						
evaluating whether a given data set will be suitable for machine learning?						
cleaning a data set for a machine learning model?						
engineering features in a data set prior to creating a model?						
setting up training and testing sets of data for a model?						
evaluating how well a model is performing?						
optimizing a model?						
determining the domain of applicability for your predictions?						

Overall/ General Skills: In general (not specific to machine learning), how skillful do you consider yourself to be at:
(1= Not at all skillful, 2= Slightly skillful, 3= Somewhat skillful, 4= Fairly skillful, 5= Very skillful. N/A= Not Applicable)

	1	2	3	4	5	N/A
Designing experiments						
Conducting experiments						
Analyzing and interpreting data						
Functioning on multidisciplinary teams						
Working independently on a research project						
Understanding professional responsibilities						
Understanding ethical responsibilities						
Communicating using oral progress reports						
Communicating using written progress reports						
Applying skills specific to your academic major						
Building on knowledge from previous coursework						
Building on skills from previous coursework						
Setting an effective schedule/timeline						
Dealing with setbacks						

Confidence: Please rate your confidence in the following areas.
(1= Not at all confident, 2= Slightly confident, 3= Somewhat confident, 4= confident, 5= Very confident. N/A= Not Applicable)

	1	2	3	4	5	N/A
I can make contributions to a research team.						
I can explain my research to other scientists.						
I can explain my research to non-scientists.						

I could suggest future research directions to my mentor regarding my project.						
I can document my research in a manner which others can read and understand.						
I can provide my peers with constructive feedback on their projects.						
I can identify research misconduct.						

Satisfaction with students in your team/ group: Please rate your satisfaction with characteristics of the students in your team or group.
(1= Very dissatisfied, 2= Somewhat dissatisfied, 3= Neither dissatisfied nor satisfied, 4= Somewhat satisfied, 5= Very Satisfied. N/A= Not Applicable)

	1	2	3	4	5	N/A
Ability to work in teams/groups						
Level of camaraderie or friendliness						
Level of communication with other members						
Level of engagement with the Skunkworks curriculum and/or project						
Group's or team's overall progress/accomplishments						

Satisfaction with Instructional Materials: Please rate your satisfaction with the instructional materials and guidance from your group/team mentor/lead
(1= Very dissatisfied, 2= Somewhat dissatisfied, 3= Neither dissatisfied nor satisfied, 4= Somewhat satisfied, 5= Very Satisfied. N/A= Not Applicable)

	1	2	3	4	5	N/A
Clarity of the education materials						
Quality of feedback on assignments or tasks						
Quality of interaction with your mentor/team lead						
Level of communication from your mentor/team lead						
Clarity of instructions other than the educational modules						

Satisfaction with Research Mentoring: Please rate your satisfaction with the research mentoring you received
(1= Very dissatisfied, 2= Somewhat dissatisfied, 3= Neither dissatisfied nor satisfied, 4= Somewhat satisfied, 5= Very Satisfied. N/A= Not Applicable)

	1	2	3	4	5	N/A
Overall quality of research mentoring						
Quality of meetings and communications						
Clarity of expectations and feedback						
Availability of your research mentor						
Support of your overall wellbeing						
Guidance you received about career options (if requested)						
Information you received about graduate studies (if requested)						

Which elements of the Skunkworks did you like the most? (For “Education Group” Students only)

_____

Was there any content that you were expecting that was missing? If so, please elaborate. (For "Education Group" Students only)

_____

Do you have any other feedback about Skunkworks that you would like to provide?

_____

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