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*Growing by Mentoring:
A Guide for Data Science for Social Good Mentors*



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Introduction

Welcome, Data Science for Social Good mentors!

We are excited that you are committed to spending the next few months mentoring students on a data science project with social impact. Your guidance are crucial to the success of the project and your students' growth as a data scientist. Besides being a learning experience for the fellows and enhancing data analysis capacity for the project partner, Data Science for Social Good program (DSSG) also provides an opportunity for you to grow as a mentor, teacher and project manager.

If this is your first DSSG experience, you can begin by going through one the following projects to get an idea of what a typical project looks like. Throughout the guide you will encounter many "activities", where we invite you to reflect on your own experiences or design materials you can use during DSSG. By the end of this guide, you will have a concrete list of materials, e.g., a learning activity for a tutorial, a project milestone, and learning goals for fellows. These activities are self-paced, and you can complete these activities on your own or with others.

Activity Go through the following DSSG projects, what are the goals of each project? What approaches did the team take? How did they present their results?

1. Identifying Factors Driving School Dropout and Improving the Impact of Social Programs in El Salvador ¹
2. Predictive Enforcement of Pollution and Hazardous Waste Violations in New York State²
3. Developing NLP Tools for Sharing of Indigenous and Community Knowledge.³

¹ Tjiptarto, D., Valdivia, A., Baltasar del Valle-Inclan Redondo. (2018). *Identifying Factors Driving School Dropout and Improving the Impact of Social Programs in El Salvador* Data Science for Social Good, Carnegie Mellon University

² Jin, J., Kamenetsky, M., Magee, D. (2016). *Predictive Enforcement of Pollution and Hazardous Waste Violations in New York State* Data Science for Social Good, Carnegie Mellon University.

³ Chow, A., Dong, H.W., & Kuang, Y. Q. (2019). *Developing Natural Language Processing-Tools for Sharing of Indigenous and Community Knowledge* Data Science for Social Good, University of British Columbia

You might notice that these projects span many application domains, e.g., education equity, environment protection, and energy industry. Their goals range from exploratory data analysis to decision making. The DSSG teams use a variety of tools, such as data visualization and predictive modeling. Nonetheless, the projects share several common features. For instance, they have clear problem statements and impacts; they involve steps in a typical data science project cycle, such as exploratory analysis and feature engineering; the deliverables often include a public presentation to showcase the project, a written report to document the analysis, and an organized Github repository to reproduce the results.

I prepared this guide as a starting point for you to design your mentoring experience. Because this guide is based on reflections of my experience as a fellow and technical mentor at Stanford DSSG summer program, I wrote this with the Stanford program as the point of reference. At the same time, I include general topics and examples from several DSSG programs, so that I hope you find the guide helpful in your program as well.

The grounding point of this guide is the *growth mindset*, the belief that (1) one's intelligence and ability develops through continuous effort, (2) challenges present opportunities for learning, and (3) we can be inspired by others' success⁴. With this in mind, this guide is composed of three sections corresponding to different areas of growth:

- *Your growth as a mentor* I invite you to reflect on what good men-

⁴ Carol S. Dweck. *Mindset: The New Psychology of Success*. Random House, 2006

tors *are* and what they *do*. This section will guide you to set goals for your experience, and provide strategies of inclusive mentoring.

- *Development of your project* This section focuses on how to manage a complex project and how to lead a team of fellows. I provide strategies to collaborate with a community partner and to facilitate team work.
- *Fellow's growth as data scientists* In this section, I invite you to think about what learning means. I will guide you to come up with concrete steps to help fellows improve their data science skills, to reflect on their own learning and work, and to help each other grow as data scientists.

In each section, I will explain relevant concepts, discuss strategies, and provide resources where you can learn more about each topic. The materials are designed such that you can read the sections in orders you prefer.

Before we start, I invite you to familiarize with your program structure.

Activity Read your program schedule, what are the components of the program? Who will participate? What are your roles?

For example, Stanford DSSG program includes the following components (see Figure 1 for an example of weekly activities):

- *Weekly group meeting* Fellows present project updates and discuss activities in the past and coming week.
- *Daily team meeting* Project team members and technical mentor(s) brainstorm ideas, plan tasks and share updates with each other.
- *Data and donuts* Fellows join Stanford data science scholars in conversation about data science topics, e.g., data visualization, A/B testing and fairness in machine learning.
- *Technical training* Technical mentors give a tutorial on data science topics, e.g., the basics of deep learning, multiple hypothesis testing, and writing reproducible manuscripts in R.
- *Data scientist talks* Speakers from academia or industry discuss their career trajectory and research topic. Topics include “Harnessing the power of big team science to discover generalizable insights in the social sciences”, “Applying computer vision to remote sensing data for environmental conservation: projects from the AI for Earth initiative”, and “Combining mechanistic + ML models in health: When, how, why, and why not?”.

Week of _____

Time	Monday	Tuesday	Wednesday	Thursday	Friday
09:00	DSSG group meeting	Project team meeting	Project team meeting	Project team meeting	Project team meeting
10:00	Project team meeting		Data and Donuts		
11:00					
12:00	Meeting with community partner	Mentor meeting		Technical training session	Social event
13:00			Faculty meeting		
15:00 - 17:00	Work on project	Work on project	Work on project	Work on project	Work on project

Figure 1: Example of weekly activities at Stanford DSSG program.

- *Visits to external partners* Fellows and mentors visit industrial partners, meeting data science professionals and learning about their work.
- *Social events* Fellows and mentors get to know each other through social activities, such as improvisation class, virtual painting, and escape room.
- *Mentor meeting* Mentors meet with organizers and faculty advisors to discuss project progress, make plans for the coming weeks, and address issues.

These events create opportunities for fellows to learn from each other, to broaden fellows' perspective about various data science applications, and encourage different perspectives on a project. Fellows are typically upper undergraduate or master's students, who have studied fundamentals in computing, statistics and software, but may not have worked on a real world problem. The project team is mentored by technical mentors and a faculty advisor, and the project is usually a collaboration with a partnering organization. The program is organized graduate student organizers and faculty advisors.

1

Your growth as a mentor

As you will be interacting with fellows regularly for a few months, DSSG provides an excellent opportunity for you to experience mentoring, whether you have served as a mentor before or not. In this section, you will reflect on qualities and behaviors of good mentors. You will set your mentoring goals as well as set goals with DSSG fellows. I will discuss two specific topics in mentoring: belonging and how to create an inclusive learning environment. Since I will ask you to set goals many times throughout the guide, I will first discuss why we set goals and what are good goals.

1.1 Why do we set goals and what are good goals?

I typically enjoy a trip more if I have planned a few stops beforehand. Even if I do not end up at the final planned destination or take occasional detours, having a few stops in mind allows me to plan my route and prepare for the trip. This example speaks to one benefit of goal setting: it provides direction and orients us towards relevant activities. Like Seneca said, “When a man does not know what harbor he is making for, no wind is the right wind.” In contrast, once goals are clear, one can develop strategies and evaluate their progress.

You might still wonder, are goals equally effective? What are good goals versus bad goals? Here, I refer you to two frameworks that categorizes good goals. The first one is conceived by Latham and Locke. In this framework, a good goal should be both *specific* and *challenging*, because a goal that is both clear and stimulating tends to motivate people to exert more effort and to persist¹. At the same time, the goal should be *manageable*, i.e., it should be perceived as attainable, and necessary resources and support should be available. One should also be *committed* to the goal and routinely analyze their progress or receive *feedback* from others, since they can adjust your both objective and approach accordingly and thus improve their performance.

¹ Gary P. Latham Edwin A. Locke. *A Theory of Goal Setting & Task Performance*. 1990

Another goal setting framework was developed by Doran from the perspective of management. A good goal in this framework should be *Specific, Measurable, Achievable, Realistic* and *Time-oriented*² (S.M.A.R.T. in short). When you write down a goal, you can ask a few questions: is this goal relevant for the long-term objective? Is there a time-frame for when I should plan to achieve the goal? What skill do I need and what resources are available? When should I re-evaluate my goal based on my progress? Though you should not modify your goals frequently, you can re-evaluate them, and the purpose of setting goals is provide a signpost with which you can measure how far you have travelled.

1.2 Setting your mentoring goals

Activity Think about a wonderful mentor you have had in the past: what are some of their qualities? What did they do that were most helpful in your (1) scientific and (2) personal development? ¹

¹ These questions are inspired from questions in the paper *The Qualities and Impacts of a Great Mentor—and How to Improve your own Mentoring* by Grogan, P., and Eviner, V., & Hobbie, S. (2013) in *The Bulletin of the Ecological Society of America*.

Perhaps your mentor was warm, supportive and positive; perhaps they suggested ideas when you were stuck on your research; perhaps they were your academic role model. All of these are important qualities. Let's say you encounter a roadblock in your project, by being positive your mentor shows that they accept you as a young scholar, and that they are confident in your ability to address the challenge. By being supportive, they encourage you to become an independent researcher and to push the boundary of knowledge in your domain. By offering guidance, they help you move forward in your work. These qualities help you develop personally and professionally, both of which are important aspects in mentoring.

1.2.1 What is mentoring?

While we may consider our peers who demonstrate academic excellence or family member who give us suggestions as our mentor, in this guide I focus on mentoring in a *formal* and *academic* setting. A mentoring relationship is formal when a mentee is assigned to the mentor, and the mentoring relationship has certain structure, length, and guideline³. I also focus on mentoring in the academic setting when mentors offer knowledge, advice, challenge, counsel and support in the protégé's pursuit of being a full member of a profession⁴.

I adopt the definition of mentoring in Packard (2016)⁵:

³ Lillian T. Eby, Jean E. Rhodes, and Tammy D. Allen. *Definition and Evolution of Mentoring*, chapter 2, pages 7–20. John Wiley & Sons, Ltd, 2007

⁴ W. Brad Johnson. The intentional mentor: Strategies and guidelines for the practice of mentoring. *Prof Psychol Res Pr*, 33:88–96, 2002

⁵ Becky Wai-Ling Packard. *Successful STEM Mentoring Initiatives for Underrepresented Students : A Research-Based Guide for Faculty and Administrators*. Stylus Publishing, 1st edition, 2016. ISBN 9781620362952

Mentoring (is) a developmental experience or a type of support intended to advance students toward an important goal.

This definition highlights three aspects of mentoring:

- Mentoring is *student-oriented*, and the objective is to guide mentee towards accomplishing a goal. Mentoring starts with understanding needs and aspirations of the mentee. In the next section, you will see a few questions to help you understand fellows' academic journey, goals, and interests.
- While the "developmental experience" refers primarily to the growth of the mentee, mentors tend to also benefit from the mentoring relationship. As Galbraith pointed out, "mentoring a powerful and passionate interaction, whereby the mentor and protégé experience personal, professional, and intellectual growth and development"⁶.
- Mentoring is a reciprocal relationship that evolves through time⁷. Thus, characteristics of a nurturing relationship (e.g., open, respectful, and authentic) make for more effective mentoring.

While each individual has their unique mentoring style, mentees typically appreciate certain attributes and conducts of their mentors. The article *Nature's guide for mentors*⁸ quotes the description of several scientists' of their mentors. The following are a few excerpts from the article:

- *Active listening and questioning* "There is always another question to ask. The questions seem innocuous but nothing is as it seems to be; there are more insights to be gained by probing away. M also never imposes her will, but she persistently keeps the questions flowing to help the answer come along."
- *Balancing direction and self-direction* "The major aspects of practice and personality are her ability to listen patiently, even when she knows better, and to point the mentored person to a more complete understanding of the issues implicit in a particular problem. This she does with deceptively simple questions that frequently do not elicit an immediate response, but ultimately allow a more rational interpretation of all the facts."
- *Skill development* "M has focused on equipping people with the skills to be fully functioning members of the scientific community, able to prepare grant applications, review manuscripts, speak at conferences and engage with scientific administrators in a constructive manner. Such a holistic approach to running a scientific group will ultimately bring enormous benefit to the group's

⁶ Michael W. Galbraith. Celebrating mentoring. *Adult Learning*, 14(1):2–3, 2003

⁷ Joyce Fletcher and Belle Ragins. *Stone Center Relational Cultural Theory: A Window on Relational Mentoring*, chapter 15, pages 373–399. Los Angeles: Sage Publications, 2007

⁸ Adrian Lee, Carina Dennis, and Philip Campbell. *Nature's guide for mentors*. *Nature*, 447(7146):791–797, 2007

alumni, giving them all the skills necessary to carve out their own niches in the academic world."

Activity Read the article *Nature's guide for mentors*. Which description do you find particularly inspiring? How does the mentor's behavior assist the personal or professional development of the mentee? Then, Thank about one or two things that you can do as a mentor. You can use Table 1 in the paper as a guide.

Now that you have seen what good mentors *do*, I retrace to the beginning of this section where you reflected on the qualities of a wonderful mentor you have had. What do you want to *be* to your mentees? What qualities do you want to demonstrate?

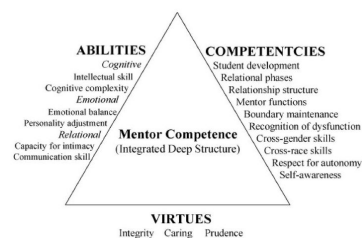
To help you formulate an answer, I introduce the *triangular model of mentor competence* from the book *On being a mentor*⁹. This framework considers three aspects of mentor competency: virtues, abilities and competency. *Nature's guide to mentors* provides many examples of competencies, and you can find more examples in Chapter 5 of the book, and now let us focus more on virtues and abilities.

I highlight two mentoring abilities from the triangular framework: emotional ability and relational ability. Emotional ability speaks to the capability to understand and manage one's emotion in life and relationships. One example of emotional ability is empathy, which is the ability and willingness to listen, understand, and reflect on others' needs and concerns. Another example is being friendly and collegial, showing genuine respect and acceptance of someone's individuality, skill and experience. An example of relational ability is congruence, where a mentor accurately and authentically communicate their experience with the mentee. Relational abilities are important because by exhibiting excellent interpersonal skills, mentors help their mentees develop their interpersonal skills as well.

We emphasize that these positive attributes can be cultivated. For instance, you may not think of yourself as a particularly warm person, and yet you can still make fellows feel welcome through your actions. To conclude this section, I invite you to reflect on how you can apply some of these concepts in your mentoring.

Activity What are your strengths and weaknesses as a mentor? Which aspects do you want to grow in? What goals do you want to set for yourself? What steps do you plan to take to make progress in these directions? (e.g. I can compliment students when they ask good questions, make good comments or have good ideas. For example, I can tell them "That's a good idea! I did not think of it!")

⁹ W. Brad Johnson. *On being a mentor: A guide for higher education faculty*. Lawrence Erlbaum Associates Publishers., 2007



1.3 Getting to know DSSG fellows

Getting to know your students not only help you connect with them, but also it allows you to tailor your mentoring based on their needs. The practice of determining the mentoring outcomes before starting a program and then plan the course of action accordingly is called *intentional mentoring*¹⁰. As you can imagine, we can help students progress towards their goals more effectively by being intentional.

1.3.1 Skills fellows can learn through DSSG

DSSG fellows are typically come from various personal and academic backgrounds. They also tend to have different motivations and goals. For instance, some of them might want to enrich their professional portfolio, others may want to be exposed to academic research; some may be interested in educational equity while others may be curious about epidemiology. Nevertheless, they all want to become more proficient data scientists, and the multifaceted activities during DSSG provide ample opportunities for fellows to grow.

The following a list of data science skills fellows can enhance through DSSG. You can use this as a reference when you think about directions your mentees might want to pursue. The list, based on *The data for good growth map*¹¹ and *Curriculum guidelines for undergraduate programs in statistical science*¹², is not meant to be comprehensive, and different skills are grouped to ease your reading.

- Contextual knowledge
 - Understanding background and purpose of a project, e.g., by reading literature and communicating with the project partner.
 - Learning domain knowledge for a specific subject and engaging with domain experts.
 - Creating a deliverable and presentation tailored to the project partner's needs.
- Collaboration skills
 - Working with team members.
 - Providing feedback to each other.
- Technical research skills
 - Managing a data set, e.g., identifying missing data, data transformation and encoding.
 - Visualizing data, e.g., emphasizing relations between variables of interest, leveraging graphical elements to facilitate comparison between different pieces of data.

¹⁰ Becky Wai-Ling Packard. *Successful STEM Mentoring Initiatives for Underrepresented Students : A Research-Based Guide for Faculty and Administrators*. Stylus Publishing, 1st edition, 2016. ISBN 9781620362952

¹¹ Dharma Dailey, Sarah Stone, Anissa Tanweer, and the Data for Good Organizer Network. *The data for good growth map: Decision points for designing a university-based data for good program*

¹² American Statistical Association Undergraduate Guidelines Workshop. *Curriculum guidelines for undergraduate programs in statistical science*, 11

- Modeling, including model selection, evaluation and communication.
- Conducting reproducible research.
- Using collaboration tools, e.g., Git.
- Becoming more fluent with statistical software, e.g., python or R.
- Designing and implementing simulations or optimizations.
- Developing mathematical understanding of a statistical model.
- Becoming a self-directed learner
 - Planning, carrying out and evaluating a data analysis approach.
 - Identifying knowledge gap and resources.
- Career development
 - Familiarizing with data science project cycle.
 - Managing a project.
 - Introducing themselves to community partners.
 - Communicating their research with other fellows, faculties and public.
 - Networking with data science professionals.

1.3.2 *Setting goals with fellows*

Now that you have seen what skills fellows can sharpen, I invite you to set personal development goal with fellows. You can use the worksheet in Table 1.1. These questions are designed to help you understand their academic journey and their professional interest. Goal setting is an *iterative* process, and I encourage you to meet with fellows regularly, and modify your answer throughout the program.

1. What has been your academic journey?
2. What are some interesting projects you have worked on or courses you have taken?
3. What's your academic goal in the next year (what are your long term goals)?
4. How can DSSG help you achieve your goals?
5. What technical skills do you want to improve?
6. Other questions about the fellow's interest or value, for example, are they interested in educational equity, environmental justice etc.?

Table 1.1: Fellows goal-setting worksheet

Activity

1. Meet with your mentees (you can use Table 1.1 as a reference); take notes from the meeting.
2. After the meeting, think about your *big dream* for your mentees: What do you want them to achieve after the DSSG program and one year after the program? With this vision in mind, write down one or two things you or the fellow can do to accomplish this. For example, if a fellow wants to improve their presentation skills, then you can spend some time to practice presentation with them. You can also encourage them to take the lead on presenting at one of the group meetings. If a fellow is interested in developing their professional portfolio, then you can connect them with data scientists, invite speakers to talk about their career trajectory, or provide resources to help them navigate data science job market.

1.4 *Fostering a sense of Belonging*

In 1967, Jocelyn Bell Burnell noticed a strange pulsing signal from the radio telescope. The signal did not look like that from a quasar, a type of active galactic nucleus with a massive blackhole in the center surrounded by an accretion disk, and neither was it the result of interference. “Immediately, I knew it was something else”. She took note of when the time the signal is expected to occur, and switched the machine to high speed setting to catch its detail. It was a string of pulses, one and a third seconds apart from each other. Later, she observed a second and a third of this signal, confirming her idea that this belongs to a new object. She had discovered *pulsar*, the pulsating radio star, which is the remnants of big star that spins and emits radio signals. The discovery would later earn her advisor Antony Hewish the Nobel prize even though she was the one who discovered and investigated the anomalous signal. The Nobel prize in physics in 1974 was awarded to Antony Hewish, for his decisive role in the discovery of pulsars, and Martin Ryle, for his observations and inventions, in particular of the aperture synthesis technique.

In several interviews, Jocelyn Bell Brunell said she has been motivated by her feeling as outsider and her imposter syndrome. “They are going to discover their mistake (of admitting me) and throw me out. I got around it by deciding I would work my very hardest, so that when they threw me out I wouldn’t have a guilty conscience”. She also described her experience in her undergraduate studies as the only girl in a class of fifty. “It was the tradition, when a women entered the lecture, all the male students stamped and whistled and

called and banged the desk. I had to face this on my own. It's nasty, yes. If I hadn't been clear what I wanted to do, I would have gone some other way."¹³

While Jocelyn Bell Burnell persisted through the scoffing, the feeling of not belonging is one of the key factors that turn underrepresented students away from the academia. As members of the data science community, we all have parts to play to ensure everyone feel that they belong. In this section, I will discuss some challenges for minority students in the academic setting and what are some strategies you can take to create an inclusive learning environment where everyone can thrive.

1.4.1 *What is belonging?*

Belonging is the perception of "being connected to others: accepted and included, to be valued members of social groups, and to contribute positively to the lives of others"¹⁴. Belonging should not require one to make efforts to "fit in", hiding parts of their identity. Rather, belonging means that every aspect of one's identity is respected and valued. In the academic setting, belonging takes additional significance: it means that one feels that they are a member of a profession or a community of practice (e.g., "I am a data scientist"),¹⁵ that their contributions are valued, and they are respected personally and recognized professionally¹⁶.

Activity Think about a situation when you feel that you did not belong in a scholarly environment, what factors contributed to your feeling? What support did you receive or wish you had received?

You might notice that when you did not feel you belong, you were anxious, more stressed and deterred from pursuing opportunities. In fact, Fisher et al. (2019) showed that while women and African American graduate students tend to publish less than their majority peers, they are more likely to publish at a comparable rate when they feel they are well-prepared for the program, accepted by their colleagues, and experience well-structured programs¹⁷. You might also notice that the sense of belonging can be affected by small gestures. For example, I felt out of place when one student refused to sit next to me during lunch. In another occasion, I felt that I belong when a professor kindly asked my opinion during a meeting and told me that they were interested to hear my thoughts. Indeed, small gestures make a big impact!

¹³ Ben Proudfoot. She changed astronomy forever. he won the nobel prize for it. <https://www.nytimes.com/2021/07/27/opinion/pulsars-jocelyn-bell-burnell-astronomy.html>, year = 2021. New York Times, Op-Docs

¹⁴ Gregory M. Walton and Timothy D. Wilson. Wise interventions: Psychological remedies for social and personal problems. *Psychol. Rev.*, 125:617, 10 2018b

¹⁵ A community of practice is defined by Wenger as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" .

Etienne Wenger. Communities of practice: A brief introduction. <https://www.nytimes.com/2021/07/27/opinion/pulsars-jocelyn-bell-burnell-astronomy.html>, year = 2011

¹⁶ Communications Team Royal Society of Chemistry. A sense of belonging in the chemical sciences

¹⁷ Aaron J Fisher, Rodolfo Mendoza-Denton, Colette Patt, Ira Young, Andrew Eppig, Robin L Garrell, Douglas C Rees, Tenea W Nelson, and Mark A Richards. Structure and belonging: Pathways to success for underrepresented minority and women phd students in stem fields. *PLoS one*, 2019

1.4.2 Why is belonging important?

Many psychologists and sociologists have recognized belonging as one of our basic social needs. In Maslow's hierarchy of human needs, "belonging and love" is considered a *deficiency need* that should be met before one can fulfill one's *growth needs*, such as the need to know, explore and achieve, and the need to fulfill one's potential.¹⁸ Through the lens of sociobiological theory, Nohria, Lawrence, and Wilson (2001) also recognize one's need to bond with others in long-term relationships of mutual care and commitment¹⁹.

In a learning environment, a higher sense of belonging enhances motivation, engagement and persistence. On the other hand, the feeling that one does not belong increases anxiety and depresses learning and performance^{20 21}. In the long term, belonging affects a student's decision to persist in an academic field. One research finds that among college students who leave STEM majors, 70% feel that they did not belong, whereas only 10% feel that they do not belong among students who stayed in STEM majors²². The same study also finds that female and minority students are more likely to feel that they do not belong. Nilanjana Dasgupta summarized succinctly in her *interview with NSF*: "Usually, people walk through the door if they have some degree of ability, interest, and curiosity about a subject. What makes them stay is belonging."²³

The research suggests that students need to feel they belong regardless of where they are in their academic journey. Moreover, we should create a welcoming environment not only in the formal setting like a classroom, but also in day-to-day interactions. Next, I will describe a few strategies you can use to foster a sense of belonging.

1.4.3 Mentoring strategies to enhance belonging

Activity Reflect on a time when someone made you feel that you belong in a scholarly setting, what did they do?

Perhaps they told you failure is part of the learning process and to cheered you on when you were struggling, perhaps they encouraged you to apply to a professional conference, or perhaps they took the time to greet you when you meet in the hallway. These small actions show that they value your growth, respect acknowledge your scholarly contribution, and respect you as an individual. Below are a few strategies that I found particularly useful, and I suggest you read the article *Ten simple rules for supporting historically underrepresented students in science*²⁴ if you would like to learn more practical tips.

¹⁸ Maslow first formulated his hierarchy of needs on 1954, and later in 1971 he refined the categories in self-actualization needs.

¹⁹ William G. Huitt. Maslow's hierarchy of needs. educational psychology interactive, 2007. Educational Psychology Interactive

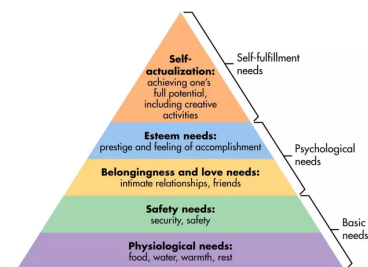


Figure 1.1: Maslow's hierarchy of needs.

²⁰ D. L. Schwartz, J. M. Tsang, and K. P. Blair. *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them*. W W Norton & Co., 2016

²¹ Vincent Tinto. Classrooms as communities: Exploring the educational character of student persistence. *J Higher Educ*, 68(6):599–623, 1997

²² Katherine Rainey, Melissa Dancy, Roslyn Mickelson, Elizabeth Stearns, and Stephanie Moller. Race and gender differences in how sense of belonging influences decisions to major in stem. *Int. J. STEM Educ.*, 5(1):10, 2018

²³ NSF Research News. 'Belonging' can help keep talented female students in STEM classes, 2016. URL <https://beta.nsf.gov/news/belonging-can-help-keep-talented-female-students->

²⁴ Suchinta Arif, Melanie Duc Bo Massey, Natalie Klinard, Julie Charbonneau, Loay Jabre, Ana Barbosa Martins, Danielle Gaitor, Rhiannon Kirton, Catalina Albury, and Karma Nanglu. Ten simple rules for supporting historically underrepresented students in science. *PLoS Comput. Biol.*, 17(9):1–16, 09 2021

Getting to know each fellow One needs to be seen, respected and accepted to feel that they belong. This means that you should connect with fellows individually, understanding their unique circumstances, academic journey and aspirations. You should take their stories seriously, listen without judgement, and treat them with respect²⁵.

During your conversations, you should also try to be aware of your own bias or prejudice, judgemental attitudes or behavior, and avoid remarks that convey stereotypes.

Examples

- Suppose you notice someone repeatedly using headphones during class in spite of your explicit instruction. Instead of telling them to remove their headphones, you can try to understand *why* they need to use them. They may have attention deficit hyperactivity disorder (ADHD), in which case background white noise is beneficial for them to listen and read²⁶. In the setting of DSSG program, suppose that you find a fellow's behavior frustrating or disruptive, rather than accusing or insisting them to change their behavior, you can discuss your point of view while being understanding and keeping an open mind.
- Take the time and effort to connect with your mentees, e.g., you can arrive a few minutes early before each session to talk to available fellows, or arrange to meet with each of them. This demonstrates that you care about their growth and motivates them to learn because it shows that their learning matters²⁷.

Reframing challenges You are probably familiar with failures and consider it part of the scientific process. However, fellows who do not have previous research experience might interpret struggling in their project as a sign that they are not good at data science, and this may trigger stress and anxiety. When you notice that a fellow is frustrated, you can help them *re-frame* the challenge as a valuable learning experience, and convey your confidence in their ability to overcome it.

The act of re-framing is important because while our interpretation of our social environment is relatively fixed, it is at the same time amenable. Like a working hypothesis, we continuously modify our perception a situation. As our interpretation of a situation changes, we also change our behavior and thus has the potential to change the outcome²⁸. In an academic study, researchers divided college freshmen into two groups. The students in the treatment group commits to being exposed to the possibility of increased belonging. When college starts, they were asked to read counterfeit survey results from

²⁵ Gail Horowitz. *Teaching STEM to first generation college students : a guidebook for faculty & future faculty*. Charlotte, NC : Information Age Publishing, Inc., 2019

²⁶ Suchinta Arif, Melanie Duc Bo Massey, Natalie Klinard, Julie Charbonneau, Loay Jabre, Ana Barbosa Martins, Danielle Gaitor, Rhiannon Kirton, Catalina Albury, and Karma Nanglu. Ten simple rules for supporting historically underrepresented students in science. *PLoS Comput. Biol.*, 17(9):1–16, 09 2021

²⁷ Lang James M. *Small Teaching : Everyday Lessons From the Science of Learning.*, volume 2nd. Jossey-Bass, 2021

²⁸ Gregory Walton and Timothy Wilson. Wise interventions: psychological remedies for social and personal problems. *Psychological Review*, 125:617–655, 2018a

senior students, which indicated that most senior students were worried about if they belonged at the start of college, but their sense of belonging gradually increased as their studies went on. Freshmen were also asked to reflect on how their own experiences echoed the survey and recorded their reflections in a video. As for students in the control group, the survey and essay topics are unrelated to belonging. The researchers collected student GPA at the start and end of college, and they found that while the intervention does not affect the GPA of European Americans, African American students in the treatment group sees a much higher improvement in GPA compared to students in the control group, decreasing the achievement gap compared to European Americans by 79%.²⁹

In this study, the counterfeit survey suggests that setbacks, rather than indicating that a student does not belong, are common and can be overcome by persistence. As a consequence, students were able to perceive challenges in a neutral light, and thus they feel less stress and perform better.

Examples

- When you notice a fellow is frustrated because of their progress, you can acknowledge their experience and feeling. Then, you can tell them that struggling is natural when our brain learns new material. You can also share difficulties you have encountered in your research; for instance, when you had to change the initial plan because of some challenges or unexpected situations. You can tell them that even if their plans do not work out, they can document their observations, which will be valuable for future researchers. Besides helping fellows re-frame, you can also communicate that learning through experiments and mistakes is part of the creative process of science.³⁰
- Be honest when providing feedback to a struggling fellow. You can affirm their talent, skill, and resilience. At the same time, you should be candid about the hard work they will need to do, perhaps in their project or courses they will need to take³¹. You can help students build their self-efficacy by being honest and provide constructive and specific feedback.

Fostering a growth mindset Mind A mindset is the established attitude held by someone. People with a *fixed mindset* tend to think intelligence is fixed, and therefore they avoid challenges, give up when they encounter obstacles, see efforts as worthless, ignore constructive feedback and feel threatened by the success of others. On the other hand, people with a *growth mindset* believe that one's intelligence can

²⁹ Gregory M. Walton and Geoffrey L. Cohen. A brief social-belonging intervention improves academic and health outcomes of minority students. *Science*, 331(6023):1447–1451, 2011

³⁰ See the paper Bell, R. et al. (2003) about how to help students become aware of the nature of scientific inquiry.

Randy L. Bell, Lesley M. Blair, Barbara A. Crawford, and Norman G. Lederman. Just do it? impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. *J Res Sci Teach*, 40(5):487–509, 2003

³¹ Gail Horowitz. *Teaching STEM to first generation college students : a guidebook for faculty & future faculty*. Charlotte, NC : Information Age Publishing, Inc., 2019

be developed. They embrace challenges, sees efforts as paths to mastery, persists in setbacks, and inspired by other people’s success, and therefore they are more likely to persevere and succeed³². We can model a growth mindset in our day-to-day interaction with fellows to foster a growth mindset.

Examples ³³

- Don’t be afraid to say you don’t know something; instead, tell fellows how you plan to find the answer. Demonstrating your learning process shows that knowledge is not innate, but can be obtained by conscious effort. You are also helping fellows learn how to learn, which helps them become self-directed learners.
- Ask open-ended and authentic questions so fellows can focus on the thinking process instead of obtaining a right or wrong answer. You can guide them to assess different approaches, and emphasize the reasoning.
- Avoid words that suggest a fixed mindset (e.g., do not talk about a “math” person) and use expressions that are indicative of a growth mindset (e.g., add “yet” at the end of a sentence that describes something that we do not master at this point in time).

Activity What are your takeaways from these strategies? List one or two things that you will try to help fellows feel that they belong.

1.5 Creating an inclusive learning environment

According to the Survey of Earned Doctorates, 593 female, compared to 1438 male students obtained doctoral degree in mathematics and statistics in a US institution in 2020. Among the 928 US citizens, only 30 are black or African American, 56 Hispanic or Latino, as compared to 118 Asian and 661 White (9 unreported). This statistics shows that female and minority students are underrepresented among doctorates compared to white or male students. While there are many reasons for this, it is important to realize that students from an underrepresented group face additional challenges in higher education because of stereotype, identity interference or previous negative experience. In this section, I focus on these additional barriers, and what you can do to help underrepresented students feel that they belong. Here, the term *underrepresented group* of students refer not only to students from a gender or racial minority group, but more generally to groups underrepresented in science, such as those from LGBTQ2S+ community, students with disabilities, and first-generation, low-income students.

³² Carol S. Dweck. *Mindset: The New Psychology of Success*. Random House, 2006

³³ These examples are from the website: Stanford Center for Teaching and Learning. Growth mindset. <https://ctl.stanford.edu/growth-mindset>

1.5.1 Challenges to belonging in the academic setting

Activity

1. List three challenges you think underrepresented students might face in higher education.
2. Watch one or two of the following videos where students discuss challenges they face as members of underrepresented minorities in undergraduate institutions and reflect again on the challenges they face. What in the video surprised you?
 - **Who We Are: First-Generation College Students Speak Out FLI at Stanford: the voices of first-gen and low income students¹**
 - **“Ask us”: What LGBTQ students want their professors to know²**
 - **What LGBT Students Want You To Know³**

¹ *First-gen, low income and claiming a community: How FLI students are transforming the university for everyone*, Stanford magazine, Video URL: <https://youtu.be/RRExHrSESxo>

² Video URL: <https://youtu.be/RRExHrSESxo>

³ Video URL: <https://youtu.be/B-G4vA6TsX4>

You may notice a few themes emerging from these videos. Underrepresented students may see few people of their identity at the university; First-generation students may feel academically unprepared and at a loss as to how to succeed in higher education (in our case, the data science workforce). Below, I summarize a few challenges underrepresented students might face.

Identity interference Because of unequal representation of different identities in a field of study, people might hold stereotypes of professionals in that discipline. For instance, one might think of a data scientist as white male wearing t-shirts and jeans, who spends hours in front of their computer writing code, from their impression after watching the movie “The Social Network”. A student who does not conform to the stereotypical image might feel that their identity is incompatible with that of a data scientist. They may even feel that their identities *interfere* with being a successful data scientist. The clashing between identities, where one identity interferes another, is sometimes referred to as *identity threat*³⁴. Research has shown that identity threat causes lower satisfaction and higher depression among female scientists³⁵. While we typically focus on social identities such as race and gender,³⁶ it might be helpful to consider other aspects of one’s life circumstances as well, such as being a mother, provider or a caretaker.

Finally, even without identity interference, students from under-

³⁴ Michael L. Slepian and Drew S. Jacoby-Senghor. Identity threats in everyday life: Distinguishing belonging from inclusion. *J Pers Soc Psychol*, 12(3): 392–406, 2021

³⁵ Isis H. Settles. When multiple identities interfere: The role of identity centrality. *Pers Soc Psychol Bull*, 30: 487–500, 2004

³⁶ Social identity typically include race, gender, socioeconomic status, sexual orientation, disabilities, religion and intersectionality, see

Northwestern Searle Center for Advancing Teaching and Learning . Social identities. <https://www.northwestern.edu/searle/initiatives/diversity-equity-inclusion/social-identities.html>

represented groups may feel they don't belong simply because there is a fewer of them in a discipline³⁷.

Stereotype threat *Stereotype threat* is the predicament that people feel that they are at risk of conforming to a stereotype about their social group. How does stereotype threat affect underrepresented students' performance? Think about a female taking a math test. She might think that if she does not do well in the test, then it confirms the stereotype that women cannot do well in math. Instead of focusing on the test, she has to divert her mental efforts to suppress these negative thoughts. The anxiety and distraction prevents her from performing optimally. In a seminal study, Steele and Aronson found that asking African American college students to indicate their race at the front of a test booklet caused their grades to drop³⁸. Since this study, stereotype threat has been observed in many social groups and settings³⁹. We note that stereotype threat is situational: for instance, while a female student might experience stereotype threat when taking a math test, the effect might disappear when the exam explicitly states that it does not measure their mathematics ability.

Previous negative experiences Underrepresented students are more prone to harassment in an academic environment, including racism and discrimination. They are also more likely to experience microaggression in their daily life. ⁴⁰ Derald W. Sue defines microaggression as "The everyday slights, indignities, put downs and insults that people of color, women, LGBT populations or those who are marginalized experiences in their day-to-day interactions with people." Microaggression can be intentional or unintentional; it can be verbal (e.g., "Everyone can succeed in this society, if they work hard enough." ⁴¹) or non-verbal (e.g., mistaking female doctor as nurse). It creates a hostile environment and may affect the physical health of those affected⁴².

1.5.2 How to create an inclusive learning environment

By reading the challenges underrepresented students face in academic setting, you have accomplished the first step to creating an inclusive environment — by becoming aware. I now describe two strategies you can use to empower your students and creating a welcoming environment for everyone.

Incorporating work in different application areas Research shows that first-generation college students tend to be attracted to careers that are prosocial, i.e., has the potential to benefit their community or im-

³⁷ Catherine Good, Aneeta Rattan, and Carol S. Dweck. Why do women opt out? sense of belonging and women's representation in mathematics. *J Pers Soc Psychol*, 102:700–717, 4 2012

³⁸ Claude M Steele and Joshua Aronson. Attitudes and social cognition stereotype threat and the intellectual test performance of african americans. *J Pers Soc Psychol*, 69:797–811, 1995

³⁹ Stereotype threat. <https://philosophy.rutgers.edu/climate-v2/climate-issues-in-academic-philosophy/stereotype-threat#datathreat>. Department of Philosophy, Rutgers University

⁴⁰ See the article [Campus Climate Survey reflects significant issues, Faculty Senate report details](https://news.stanford.edu/report/?p=6010) at the URL <https://news.stanford.edu/report/?p=6010>.

⁴¹ In this example, the speaker attributes disparate outcome to people's laziness and denies the effect of systemic racism, see

Microaggressions part i: What are they, how are they harmful and what to do if you commit one? <https://vpfo.ubc.ca/2021/03/microaggressions-part-1/>, how-published = Vice-President Finance and Operations Portfolio, University of British Columbia

⁴² Jenée Desmond-Harris. What exactly is a microaggression? <https://www.vox.com/2015/2/16/8031073/what-are-microaggressions>

prove the well-being of others⁴³. One way to help students feel they belong is to affirm their values and to demonstrate lead to prosocial outcomes.

Examples

- Try to learn about the value and interest of your students, and provide examples that aligns with their interest. For example, if students are interested in global warming, then you can use an animated visualization of the global temperature as an example of data visualization.
- Feature work of a diverse group of researchers. students are more likely to feel that they belong and persevere through challenges if they see people of their identity succeed. ⁴⁴

Use micro-affirmations The opposite of microaggression is *micro-affirmation*, which focuses on active listening, recognizing and validating experiences and affirming emotional reactions⁴⁵.

Examples

- Give heed to circumstances of each fellow. For example, if one of your students has to work in the afternoon, you can take the initiative to ask fellows to coordinate time that can work for everyone.
- Affirm fellows' contributions and celebrate their success. For example, when they asked a thoughtful question or make a stimulating observation, you can say "That's a very interesting observation!".
- You can ask for fellows' feedback and identify suggestions that you can implement.

Activity What can you do as a mentor to create an inclusive learning environment?

1.6 Other topics in mentoring

1.6.1 Cross-racial mentoring

Since DSSG fellows usually come from diverse cultural backgrounds, I want to discuss some challenges of cross-racial or cross-cultural mentoring and what you can do to address them. Materials in this section are adapted from Chapter 13 of *On being a mentor*⁴⁶.

⁴³ Matthew C. Jackson, Gino Galvez, Isidro Landa, Paul Buonora, and Dustin B. Thoman. Science that matters: The importance of a cultural connection in underrepresented students' science pursuit. *CBE Life Sci. Educ.*, 15, 9 2016

⁴⁴ You can even consider a spotlight assignment and ask students to share stories of a scientist who inspires them. This website(URL: <https://scientistspotlights.org/about-us/>) highlights scientists from a variety of background.

⁴⁵

⁴⁶ W. Brad Johnson. *On being a mentor: A guide for higher education faculty*. Lawrence Erlbaum Associates Publishers., 2007

Challenges in cross racial mentoring Mentees may feel stress and isolation if they have experienced bias, rejection or hostility before. They may worry that they need to discard their racial or cultural identity to fit in. They may feel distrust or skeptical about the support they would get from their mentors if they have experienced stereotypes, e.g., the stereotype that Asian students do not need mentoring. It might take some time for them to be familiar with how to be a successful mentee in the Western culture. For instance, because Asian culture focuses on collectivism, Asian students might not want to overburden their mentor, and therefore they may find it difficult to communicate personal needs.

On the other hand, mentors might have misconceptions about working with students from racial groups different from their own. For instance, they may think that only same race mentoring can be effective. Or they may think there's no difference when mentoring students of the same or different race. They might even hold negative stereotypes; this might lead them to withhold their support for students until they have proved against the stereotype, or they might overcompensate or become overprotective.

To be an effective mentor, you should recognize the stereotypes you might hold, appreciate differences, and deliberately work towards enhancing your capacity to work with students from different cultures.

Strategies for mentoring students from another race or culture

- Recognize stereotypes, both those that are common and whose that you might personally hold.
- Appreciate individual differences. Rather than seeing students from different culture as a group, see each individual student as unique and complex.
- Work to enhance your cross-culture competence. For instance, spend time to learn the cultural heritage of your minority mentee, recognize racially related stress, and openly address cultural differences.
- Establish trust with your mentee.
- Listen for your mentee's preference when addressing racial differences.
- Encourage mentees to build secondary relationships, e.g., encourage African American students to connect with African American student association.

2

Development of your project

As a technical mentor, you may need to take on the role of a project manager, carefully planning the project, guiding your team along the way, and facilitating communication with your project partner. In this section, I focus on three topics:

- *Collaborating with your project partner* DSSG team often works with an organization (we refer to them as the “project partner”) to solve a problem or answer a question. This section discusses strategies about how you can *initiate* and *sustain* collaboration with your project partner to ensure that DSSG project successfully addresses their need. You will outline a project milestone at the end of this section.
- *Leading effective team meetings* During DSSG, you will meet with your team daily to brainstorm ideas, share progress, provide feedback, and set goals. We describe several discussion moves to help you achieve this during team meeting, while helping fellows grow as data scientists and team players.
- *Housekeeping* This section offers a list of questions to help you decide how to structure and organize team work and project materials.

2.1 Collaborating with your project partner

As a scholar, you might be more familiar with curiosity-driven research, where you determine a topic of your interest and leave implementing your theory or method to practitioners, as compared to *collaboration* between a research team and a project partner. Though it takes some effort to engage your project partner, your endeavor will be fruitful because DSSG projects have the potential to make a real impact, not only through innovative research, but also through addressing an issue that affects people!

I start with a case study (from my personal experience): what elements in this example enhance collaboration and how can this project be improved?

2.1.1 *A case study*

Activity Read the description of the following DSSG project. What did the team do to facilitate collaboration with the project partner? How can the project be improved?

In the project “Forecasting Platelets Blood Bag Demand to Reduce Inventory Wastage at the Stanford Blood Center”, we collaborated with a medical officer at Stanford Blood Center to develop an inventory management strategy for platelets blood bags.

At the start of the program, our project partner gave us a tour around the blood center. We saw platelets blood bags in the refrigerator, maintained at a stable temperature and being gently shaken from side to side. After the tour, he told us what platelets are and the challenge in managing the platelets inventory. Platelets are cell fragments in our blood that form clots and stop or prevent bleeding. A patient usually requires platelets transfusions in one of two situations: when they experience severe blood loss during a surgery, or when they do not have the capability to produce platelets. The blood center orders a certain number of blood bags according to whether it is a weekday or weekend. Because platelets blood bags have a short shelf-life, it is easy to incur waste by ordering too large amount.¹ At the same time, the blood center wants to prevent shortage because of the critical importance of platelets. Therefore, they want to develop a data-driven method to determine how many blood bags to order every day.

¹ Platelets is particularly valuable because a donor can only donate platelets twice a month

During our discussion with our project partner, we noticed that they were concerned about using a “black-box” strategy, where an algorithm recommends a number without any explanation. Therefore, we decided to predict platelets demand first, leaving to others the task of leveraging our predictions to devise an inventory management strategy. After exploratory data analysis, we noticed that sometimes a patient needs several blood bags during a serious surgery, while other times, one patient comes to the hospital regularly for platelets transfusion. Based on this observation, we decided to separately consider patients who undergo severe surgery and those who need regular transfusions. We hypothesized that separating the two sources of usage would enable us to arrive at a more accurate prediction.

We implemented different models to predict platelets demand and evaluated our models using past data. We also met with our

project partner each week to present our progress and obtain his feedback on our approaches. We applied our model to historic data and found that it was able to predict platelets demand more accurately compared to predicting by the average number of blood bags used, which does not use any information about demand. However, our project partner was not able to deploy our model because the hospital changed their data base and we did not discuss how to implement our model at the end of the program.

2.1.2 Strategies for effective collaboration

The DSSG project in the case study was a collaborative effort in the sense that

1. The project partner brought a problem, data, domain expertise and their value orientation.
2. The DSSG team brought analytical skills, such as data visualization and modeling. The project partner's domain knowledge inspired the team's modeling approach.
3. The DSSG team and the project partner decided project objectives together.
4. Both parties were aware of their roles in the project and dedicated a fixed time to discuss progress and provide feedback.

This kind of collaboration bears certain resemblances to community-based participatory research (CBPR), which can be defined as “an approach to research that involves collective, reflective and systematic inquiry in which researchers and community stakeholders engage as equal partners in all steps of the research process with the goals of educating, improving practice or bringing about social change.”² I draw some ideas from studies of CBPR, mainly from the following two articles, and complement them with examples of DSSG projects or CBPR.

- *Community-Engaged Research with Community-Based Organizations: A Resource Manual for UCSF Researchers* by Pasick, R. et al.³
- *Meaningful community collaboration in research* by Swann S.A., Campbell, A.R. and Murray, A.R.C.V.J.N.M.C.⁴

Engage your project partner in every stage of your project You should arrive to a shared problem definition, analysis strategy, interpretation of results⁵. You should take the initiative to organize regular meetings and communicate questions, progress and concerns.

² Marie-Claude Tremblay, Debbie H. Martin, Alex M. McComber, Amelia McGregor, and Ann C. Macaulay. Understanding community-based participatory research through a social movement framework: a case study of the Kahnawake schools diabetes prevention project. *BMC Public Health*, 18(1):487, 2018

³ Rena Pasick, Geraldine Oliva, Ellen Goldstein, and Tung Nguyen. *Community-Engaged Research with Community-Based Organizations: A Resource Manual for Researchers*. Community Engagement Program, Clinical and Translational Science Institute at the University of California, San Francisco

⁴ Shayda A. Swann and Amber R. Campbell and Valerie J. Nicholson Melanie C.M. Murray. Meaningful community collaboration in research. *B. C. Med. J.*, 62(9):340–341, 2020

⁵ Lisa Cacari-Stone, Nina Wallerstein, Analilia P. Garcia, and Meredith Minkler. The promise of community-based participatory research for health equity: A conceptual model for bridging evidence with policy. *Am J Public Health*, 104:1615–1623, 2014

Example: DSSG project “Algorithmic Equity Toolkit”⁶

Community civil activists have been concerned about the expansion of automated decision system (ADS), such as facial recognition systems. Because such systems are hard to comprehend, it is challenging to determine their impact. The DSSG team developed a toolkit, which includes education material about the technology, a guide to help community civil activists distinguish an ADS from a surveillance tool, and a questionnaire to identify potential harms of such tools when deployed by government agencies. In the project website, fellows described their process of developing their toolkit. The team met with the project partners to understand their work, mission and need.⁷ The team then narrowed down the audience of their toolkit to focus on civil rights advocacy, grassroots organizations, and members of the general public⁸. Each week, the team designed a new prototype, solicited feedback from the project partner, and updated their design based on the feedback. To evaluate their toolkit, they designed a survey to get both objective data, e.g., how well their project partner understand relevant concepts, and subjective feedback, e.g. how useful is the toolkit. Finally, they invited data scientists to evaluate the accuracy of their education material.

Promote co-learning You and your project partners might view a problem from different perspectives, and you can both learn from each other. For example, the DSSG team can gain domain knowledge while the project partner can learn about the technical approach.

Example: DSSG project “Developing Ensemble Methods for Initial Districting Plan Evaluation”⁹

In this project, fellows developed a user guide on how to generate district maps that account for state-level redistricting rules, how to evaluate trade-offs in selecting maps, and how to test whether existing maps are fair and representative. In a blog post¹⁰, fellows described how the project partner influenced their conceptual understanding of the project. One fellow mentioned “Engaging with stakeholders has helped ground our work in reality. By talking with experts from a variety of backgrounds, [...], we have gained insight on the practical considerations involved with redistricting.” Another fellow mentioned “Meeting with people who are engaged in redistricting has given us invaluable insights into this process and helped us to develop outputs with these stakeholders in mind.” Learning from their stakeholders motivated the team to orient their work towards practical application, bridging the gap between theory and practice that often occurs in research.

⁶ Corinne Bintz, Aaron Tam, Vivian Guetler, and Daniella Raz. Algorithmic equity toolkit. <https://uwescience.github.io/AEKit-website/>, 2019. Data Science for Social Good, University of Washington.

⁷ The project partners in this work are the American Civil Liberties Union, the members of the Community Centered Tech Coalition, specifically Densho and the Council on American Islamic Relations.

⁸ Michael Katell, Meg Young, Dharma Dailey, Bernease Herman, Vivian Guetler, Aaron Tam, Corinne Bintz, Daniella Raz, and P. M Krafft. Toward situated interventions for algorithmic equity: Lessons from the field. pages 45–55. Association for Computing Machinery, 2020

⁹ Rowana Ahmed, Katherine Chang, Ryan Goehring, and Michael Souffrant. Developing ensemble methods for initial districting plan evaluation. <https://uwescience.github.io/DSSG2021-redistricting-website/>, 2021

¹⁰ Emily Keller. Data science for social good team builds tools to support fairness in computational redistricting, 2021. URL <https://escience.washington.edu/data-science-for-social-good-computational-redistricting/> eScience Institute, University of Washington

Be flexible Many challenges can arise during the project. For example, your project partner may not be able to obtain the data on time, or they may not be available for a certain period of time. You will need to be flexible during unforeseeable circumstances and be open to taking alternative approaches.

Example: DSSG project “Geography, Equity, and the Seattle \$15 Minimum Wage Ordinance”¹¹

This project aimed to understand the effect of increasing minimum wage on low-income community. Particularly, the team focused on three issues pertinent to the lives of residents: housing burden, residential displacement and commute. The team used Washington Merged Longitudinal Administrative Data (WMLAD) for their analysis. Because this data contains highly sensitive information, such as employment, earning, residential address, etc., it is only accessible through a remote enclave with no internet. To use this data, the fellows developed a specialized workflow and met with state IRB members to discuss privacy considerations for using this data. Instead of becoming discouraged because of the inconvenience, the team reaffirmed their commitment to privacy and equity, and embraced the challenge as an opportunity to learn how to write efficient code. They also created a workflow and recommendations for future researchers who work under the same constraint.

¹¹ James Lamar Foster, Delaney Glass, Christopher Salazar, and Mahader Tamene. Geography, equity, and the seattle \$15 minimum wage ordinance. <https://uwescience.github.io/MinWA/>, 2021

Be respectful and demonstrate curiosity Respect and curiosity are important to build trust in any relationship; it is especially important in a DSSG project since the DSSG team is an outsider to the community.

Example: the “Messengers for Health” project¹²

This project is a collaborative effort between an American Indian community and academic researchers to increase Crow women’s participation and knowledge regarding cervical cancer screening and prevention. The researchers intentionally built trust between community and themselves through many efforts. They attended anti-bias training to gain awareness of their personal history and bias. They learned about the history and the culture of the tribe, as well as the historical context of their research. They attended social and cultural events. They were transparent about their intentions, and they acknowledged and engaged the expertise of the community partner. Their efforts resulted in an 11-year long partnership. Over the years, more community members became willing to participate in the project. The research team were also approached by male community members to develop a project on men’s health issues on the reservation. The Messengers for Health project were also invited to Crow Fair, a significant social event for the tribe.

¹² Suzanne Christopher, Vanessa Watts, Alma Knows His Gun McCormick, and Sara Young. Building and maintaining trust in a community-based participatory research partnership. *Am. J. Public Health*, pages 1398–1406, 2008

Be clear about your expectations For instance, be upfront about how often you expect to meet with your project partner, what decision they need to make and when do you expect their response. You should be transparent about your responsibilities and how much time you and the team will devote to the project. If you plan to write an academic paper, you should specify the roles of the DSSG team and the project partners, and if possible, provide guidelines that both of you will follow.

Be committed to disseminating and transferring knowledge Not only should you provide reproducible and documented code, but also you should report your analysis and communicate your results in a way that people without data science expertise can understand them.

Example: “Working with the Los Angeles House and Ball Communities”¹³

Researchers in this study aimed to develop interventions to reduce AIDS risk among the House and Ball communities in Los Angeles. Houses are primarily composed of African American men who have sex with men under 30 who perform at Balls, which are competitions focused on dance, gender expression, sexuality and fashion. The researchers reflected that designing intervention is difficult, because “the community members need to think through what is it about their communities that may put their members at risk”, while at the same time, “it can also be an experience that empowers the community to not only work to address those aspects of risk but also identify and embrace the sources of support that exist and build on those sources to create a safe and healthy environment. ”

I hope you find inspirations from these case studies and feel more confident about collaborating with your project partner! To conclude, I highlight two elements underlying these suggestions: *mindset* and *structure*. You bring to the partnership not only your research expertise, but also your creativity, patience, humility, respect, and commitment to addressing issues faced by the community¹⁴. To facilitate communications, you should set up regular meetings and clarify how to communicate with your project partner. The goal of first few meetings is for you and your project partner to come to a shared vision for the project.

2.1.3 *Deciding on a project vision with your project partner*

A project vision provides focus and inspiration at the beginning, and it will continue to evolve as the project progresses. Below, I provide a few prompts you can discuss with the project partner.

¹³ Southern California Clinical and Translational Science Institute Community Engagement. Toolkit for developing community partnership. https://sc-ctsi.org/uploads/resources/DevelopingCommunityPartnerships_Toolkit.pdf

¹⁴ Rena Pasick, Geraldine Oliva, Ellen Goldstein, and Tung Nguyen. *Community-Engaged Research with Community-Based Organizations: A Resource Manual for Researchers*. Community Engagement Program, Clinical and Translational Science Institute at the University of California, San Francisco

1. *What questions do you want to answer? What problems do you want to address?*

Often times your partner have a broad goal in mind, and you will need to work with them to refine it to a list of concrete and tangible research questions. For instance, in the DSSG project “I-405 HOT Lane Equity”¹⁵, the team used Washington State Department of Transportation traffic data, combined with other data sources, to identify whether constituents would be unduly impacted by highway tolls and other transportation management policies. The team narrowed down their project scope into three specific questions: how are the I-405 HOT lane facility’s benefits and costs distributed among and within different groups of users? Are there any inequitable distributions? What policy implications or recommendations can we make to address potential inequities?

As another example, in one CBPR study, researchers originally planned to identify options to prevent cervical cancer in an under-resourced community in Cape Town, South Africa. After discussing with community members, they refocused their research interest from cervical cancer to “cervical health,” acknowledging the broad epidemiological and social impact on women’s health¹⁶.

2. *What is the impact of answering this question/addressing this problem?*

Understanding the benefit of the project directs your team to focus on the need of your project partner and provides an important perspective from which you evaluate your work. It also helps to motivate you and your team as you work through many challenges during the program.

3. *Which community is impacted by the project?*

I stress the community as a stakeholder, even though you do not directly engage with them, because they are often directly impacted by your research. Bearing them in mind motivates you to confront ethical implications of your analysis. During the project, you should continuously ask questions such as “from whom are the data collected?”, “what source of bias is encoded in the data?”, “how to ensure our product is fair?” etc.. DSSG programs emphasize ethical problem solving and the starting point is recognizing the community impacted by your research.

Neglecting bias in the data can lead to grave consequences. For example, the city of Los Angeles employed a predictive policing company to decide which neighborhoods in LA to patrol more heavily¹⁷. The model was based on both historical crime data as well as crime pattern in recent periods. Because historical data encodes past bias in the criminal justice system, inferring current

¹⁵ Shirley Leung, Cory McCartan, Kiana Roshan Zamir, and CJ Robinson. I-405 hot lane equity. <https://uwescience.github.io/hot-lane-equity/>, 2019

¹⁶ Maghboeba Mosavel, Christian Simon, Debbie van Stade, and Mara Buchbinder. Community-based participatory research (cbpr) in south africa: Engaging multiple constituents to shape the research question. *Soc. Sci. Med.*, 61 (12):2577–2587, 2005

¹⁷ Los Angeles Police Department ended their contract with the company, PredPol, in 2020. See

Johana Bhuiyan. LAPD ended predictive policing programs amid public outcry. a new effort shares many of their flaws, 2021. *The Guardian*

criminal activity based on past data tends to result in disproportionate patrolling of neighborhoods of color^{18,19}. In this situation, keeping the attention on the community impacted — the residents of LA, and in particular the marginalized groups — would lead to a different approach. For instance, one might question the historical bias in the data, consider an auditing process for an algorithm, or even think about how to build trust from community.

¹⁸ Catherine D'Ignazio and Lauren F. Klein. *Data Feminism*. The MIT Press, 2020

¹⁹ Stop LAPD Spying Coalition. *Before the bullet hits the body – dismantling predictive policing in Los Angeles*, 2018

4. *What deliverable would be useful for you? What aspect of the deliverable is important to you?*

There are many types of deliverables you can provide, for example, detailed analysis, an algorithm or a software, a policy recommendation etc.. Clarifying deliverables can help you prioritize your work. Your project partner's value can also shape your choice. For example, when the project goal is prediction, type II error might be more important than type I error, as in the case in our partnership with the blood center. Your project partner might value the transparency and explainability of your algorithm. Sometimes, they most appreciate that your results are communicated in clear and nontechnical language.

5. *What are some resources for the project? What data are available?*

You can consult your project partner about background information and project context, e.g., related literature, news stories and legislation. You might be able to build your work on previous research the project partner has conducted on a similar problem.

Since data is critical to DSSG, you need to obtain the data source before the program starts so the project can hit the ground running. If your project partner has collected the data, you need to examine them critically: are they sufficient to address the question? If the project partner still needs to collect more data, then you can provide feedback on what data they can collect.

6. *When should we meet and what is your preferred way to communicate?*

You can suggest a few options to your project partner, e.g., email, slack, in-person meeting or Google meet. You should also clarify who you can contact for specific questions. You should schedule meetings before the program starts and clarify with your project partner when will be unavailable.

2.1.4 *Project milestones*

After a few meetings, you should have some ideas about what the project can accomplish, who will participate and with which roles, and what resources are available. Now it is time to draft milestones!

The milestones makes it easy to communicate progress with your project partner, and provide a reference with which you can troubleshoot. I will borrow ideas from the book *10 Steps to Successful Project Management*²⁰. Since everyone has a different style, I encourage you to explore approaches that are most suitable for you.

Step 1 Outline the goals of the DSSG project.

Step 2 List what the project team needs to do in order to achieve the goals at a high-level, such as “fit a statistical model”.

Step 3 Identify what and when you need input or feedback from your project partner.

Step 4 Estimate how long each task would take. At this point, you might break down each task into more granular activities. For example, you can write detailed steps for tasks you listed in step 2, such as “fitting a random forest”, “select parameters” and so on.

Step 5 Write detailed steps in a document. You can highlight project milestones in the document.

Step 6 Visualize the project trajectory and dependencies using a Gantt chart (Figure 2.1 shows an example).²¹ Each row in the y -axis indicates tasks one individual should accomplish, but you can also devote one row to each task. The x -axis indicates time or date. The starting and ending point of the project is marked by diamond shapes, and the duration of each task is marked by a rectangle. The relations between tasks determine the starting time of different tasks, but you can also explicitly note task dependencies by connecting tasks along a trajectory.

Activity Draft the project milestones and discuss them with your project partner.

2.2 Leading effective team meetings

An effective team meeting ensures everyone is on the same page and sets a positive tone for the day. During the meeting, the team can share progress, brainstorm ideas and divide tasks. Unlike a workplace setting, where a project manager would assign tasks to each team member, you will achieve these functions by facilitating team discussions. Through discussions, the fellows can discover a solution together, practice critical thinking and reflect on their work.²²

In this section, I will discuss the structure of a discussion and what language you can use at each step. I also describe two common scenarios you might encounter during team discussions.

²⁰ Lou Russell. *10 Steps to Successful Project Management*. Association for Talent Development, 2007

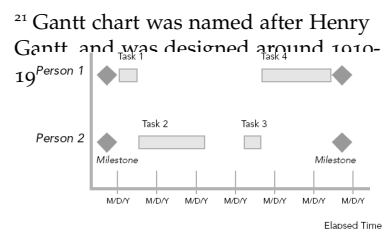


Figure 2.1: Example of Gantt chart (Figure 6.3 in the book)

²² In the article *The dreaded discussion: Ten ways to start*, the author stresses the importance of letting students discover themselves: “The key to effective retention of learning, I believe, is in owning the discovery. Emerson wrote in his journals that a wise person ‘must feel and teach that the best wisdom cannot be communicated (but) must be acquired by every soul for itself’. My primary strategy as a teacher is to structure situations in which students have as many opportunities as possible to acquire wisdom for themselves; that is, to own the discovery of a new learning insight or connection and to express that discovery to others”.

Peter Frederick. *The dreaded discussion: Ten ways to start*. *Improving College and University Teaching*, 29(3): 109–114, 1981

2.2.1 Elements of a discussion

The three basic components of a discussion are *questioning*, *listening* and *responding*. By asking questions, you can guide the discussion, clarify information and probe fellows' learning. By listening to fellows' responses, you can gauge their understanding or misconceptions. Responding allows you to follow-up with more questions or information.

Posing a question Different questions elicit different types of answers and serve different purposes. The following are a few types of questions you can ask, and you can find more types of questions in the handout *A typology of questions*²³.

- *Clarifying question* Ask fellows to explain their ideas or work.

Examples

- What's an example of what you said? What do you mean that ...?
- I think you meant ..., is that correct?
- I am confused about ..., can you explain more?

- *Challenging questions* Ask for supporting evidence, or ask fellows to explain their reasoning or assumptions.

Examples

- How do you know this?
- What information do we need to verify this hypothesis?

- *Relational questions* Encourage fellows to connect different pieces of information.

Examples

- How does this new information relate to our work?
- How do these two ideas compare?

- *Open-ended questions* Encourage fellows to brainstorm new ideas.

Examples

- Any ideas on what features we might consider in our model?
- What should we include in our deliverable?

- *Priority questions* Encourage fellows to synthesize what has been discussed to a list of actionable items.

Examples

²³ The Derek Bok Center for Teaching and Learning, Harvard University. Leading discussions. <https://bokcenter.harvard.edu/leading-discussions>

- How would you go about selecting variables?
- What’s the first step?
- What will you do next?

Listening to responses Listen actively and observe the quality of fellows’ responses: do you notice any misconceptions? are they able to elaborate on their ideas? are their thinking logical? how do they interact with each other? You might want to wait for a few seconds before you respond to encourage fellows to reply to each other.

Follow-up There are three types of follow-up moves:

- *Confirming* You can confirm a fellow’s response, or draw connection between their idea with other research. For example, you can say “That’s a good idea! I’m glad you brought this up!”, or you can explicitly tell them that you agree.
- *Rejecting/Challenging* You might point out misconceptions or inconsistencies in a fellow’s response. You can also challenge them to clarify or extend their ideas. For example, you might ask “Can you apply this idea to another situation, if so, what else do you need?”.
- *Eliciting responses* You can encourage other fellows to reply. For example, you can ask “What do you think about what we just said?”.

You can read more about follow-up moves in the handout *Techniques for responding to students in discussions*²⁴ and Chapter 3 in the book *The art of discussion-based teaching: opening up conversation in the classroom*²⁵.

2.2.2 Structure of a discussion

Now that you have seen basic elements of a discussion, you can use them throughout a meeting. Yet you might still be wondering: How do I start a discussion? What do I do when discussion goes off track? In this section, I discuss five discussion moves: framing the discussion, encouraging deeper answers, broaden perspectives, refocusing the discussion, closing discussion. Materials here are based on the presentation *The art of leading discussions for sustainable learning*²⁶.

Framing a discussion At the opening, you should let fellows know what topic do you want to discuss and how is it related to their learning or the project; this is the guiding theme that you will return to throughout the discussion. Perhaps you want to clarify a concept together, to solve a problem, or to solicit opinions. It might be helpful

²⁴ The Derek Bok Center for Teaching and Learning, Harvard University. Leading discussions. <https://bokcenter.harvard.edu/leading-discussions>

²⁵ John E. Henning. *The art of discussion-based teaching : opening up conversation in the classroom*. New York : Routledge, 2008

²⁶ Andrea Taylor. The art of leading discussions for sustainable learning. <https://drive.google.com/file/d/1kpmf36PwnZS1MHwaPATMRjgixfQ6GU0Y/view>

to set norms with your team at the beginning as well. For example, you can remind them that they should be respectful towards each other and everyone should participate equally.

Encouraging deeper answers After you solicit a few responses, you can encourage fellows to think deeper. For example, you can ask them to explain, describe evidence, or draw connections with other ideas. Make sure to be curious when asking questions.

Broaden perspectives Now that you have discussed one or two ideas in deep, you can encourage fellows to think about alternative ideas. For example, you can say “This is a great perspective, let’s hear another perspective”, or “Are we missing anything? What issue have we not considered?”

Refocus the discussion Sometimes, you need to re-focus the discussion to one specific point. For instance, you can say “We have a few options on the table, let’s focus on one point at a time.”, or you can tell them you want to focus on one idea by saying “Let’s hold off that thought for a moment and come back to that later. Let’s discuss this point first”. You can also ask fellows how they might reconcile different ideas.

Closing the loop At the end, you should summarize what has been discussed, or you can ask fellows to summarize. You might ask them “What are your takeaways?”, “How does what we discussed today relate to the project?”, or “Why should we care about these issues?”

2.2.3 Challenges you might encounter

I now describe two scenarios you might encounter during your team meetings. The suggestions are motivated by several sources^{27,28,29,30}.

Activity Think about how you would address the issue before going through the strategies. If you are working with others, then I encourage one of you to lead a short discussion about each scenario and use it as an opportunity to try the discussion moves.

Unequal participation You notice that one or two fellows are particularly active and tend to dominate the discussion. At the same time, another fellow is left out.

Strategies If you notice that some fellows do not participate much, you can encourage them to speak up by making them feel more comfortable about sharing. For example,

²⁷ The Derek Bok Center for Teaching and Learning, Harvard University. Leading discussions. <https://bokcenter.harvard.edu/leading-discussions>

²⁸ Yale Poorvu Center for Teaching and Learning. Effective class discussions. <https://poorvucenter.yale.edu/EffectiveClassDiscussions>

²⁹ Santiago Mejia. Leading effective discussions. <https://teaching.uchicago.edu/resources/teaching-strategies/leading-effective-discussions/>. Chicago Center for Teaching and Learning

³⁰ Eberly Center Teaching Excellence & Educational Innovation, Carnegie Mellon University. Discussions. <https://www.cmu.edu/teaching/design/teach/design/instructionalstrategies/discussions.html>

- You can start the team meeting with an icebreaker to help fellows get to know each other.
- You can invite fellows to participate by “warm calling”: letting the fellow know that you would like them to answer a specific question and ask them to prepare beforehand.
- You can remind fellows of their strengths, that you value their perspectives and there is no right or wrong answers. You can remind them that this is a learning process for everyone on the team.

If a few fellows tend to dominate the discussion, you might want to set some norms with the team. For instance, they might agree not to interrupt, and make sure everyone has shared before speaking a second time. You can also set up a structure to ensure everyone can participate; for instance, you can ask fellows to talk in turns.

Though in this scenario you noticed one fellow did not participate, in practice you might not be aware that some voices are missing because you might be focused on leading the meeting. To avoid blind spots, you should keep track of fellows’ participation. You can also meet with them individually to ask how they feel during team discussions, and usually they will bring up their frustration during individual conversations.

Fellows not responding to each other You notice that you are the only one responding to fellows, but they are not responding to each other.

Strategies Team meeting is a good place for fellows to learn how to work together, build on each other’s ideas, and provide constructive feedback. If you notice that they do not respond to each other, you can remind them to do so because it is important to catch up with each other’s work and decide together what’s the best way for the team to move forward.

Sometimes fellows may not know how to respond in a discussion, and in this case you can demonstrate active listening and quality responses. You can also teach fellows different roles in a discussion³¹.

Finally, you can explicitly ask for fellows’ opinions. For example, you can ask one fellow to comment on the connection between another fellows’ work and their own, or ask a question.

³¹ Stephen D. Brookfield and Stephen Preskill. *The Discussion Book : 50 Great Ways to Get People Talking*. San Francisco, CA : Jossey-Bass, a Wiley Brand, 1 st edition, 2016

2.3 *Housekeeping*

As the team leader, you should guide fellows to organize their project materials and help them collaborate. The following are some questions you can think about before the project starts. I suggest that you

start with an idea of your own and also work with your fellows to agree upon something you would do as a team, and be consistent throughout the program.

1. How shall we communicate within the team? (e.g., when should we use slack and when to use email?)
2. How shall we organize the project folder? (e.g. you might want to create a few folders, such as resources, tasks, presentations and meeting notes. As the project progresses, the team might need to create more folders to keep track of new notes)
3. How shall we organize our code? (e.g. you can use *Cookiecutter data science*³² as a starting point, but usually how you organize your code will depend on your project)
4. How shall we communicate progress and provide feedback to each other? (e.g. comment on each other's work during team meeting)
5. How would you keep track of the task of each team member? (e.g. perhaps everyone can write down their tasks in a shared document, or use [task list in Github](#))
6. How shall we communicate with project partner/faculty member? (e.g. perhaps you want to prepare some slides each week, or you might create a notebook and each fellow can rotate to take notes)

³² Cookiecutter data science.
<https://drivendata.github.io/cookiecutter-data-science/>

Activity Think through these questions, and discuss with fellows during the first week.

3

Fellow's growth as data scientists

For many fellows, the Data Science for Social Good program provides a valuable and engaging learning experience. Because the projects are interdisciplinary, fellows usually need to acquire specific skill; for example, they might need to learn game theory or use Structured Query Language (SQL). In addition to technical skills, they learn how to collaborate when working on a complex project, e.g., how to convey ideas, keep each other updated, share intermediate products, and come to a consensus. Besides interacting with each other, they might need to present their work to a community partner who usually does not have technical expertise, and thus fellows need to be able to explain concepts in plain language. Even more, DSSG may be the first time they apply their data science skills in a new scenario, where they identify an appropriate procedure, implement their ideas and refine their methods. Through this process, fellows deepen their understanding and generate new insights. All of these are new experiences, and in fact, they might be intimidating for some fellows. You should be prepared to communicate to your team that DSSG provides a strong learning experience and that you are committed to supporting them throughout the process.

The many possible areas of growth are mirrored in the breadth of approaches you can use to support them. For example, to help fellows gain technical skills, you can give them a group or individual tutorial, or you can probe their learning in conversations. To enhance communication skills, you can model effective communication and provide a list of suggestions to help fellows improve their presentation. To guide fellows to reflect on their learning, you can ask them to plan their approach, describe their reasoning, and provide each other feedback. These are but a few examples. In this section I will focus on three instruments to support fellows' learning: (1) cultivating an collaborative learning environment, (2) cultivating meta-cognitive skills, and (3) incorporating active learning in your tutorials. There are of course many other teaching strategies, and I pick these three

because they are particularly applicable to the structure of the DSSG program. I refer you to the following two books if you are interested to learn more about teaching and learning.

- *How learning works: Seven Research-Based Principles for Smart Teaching* by Ambrose, S.A. et al. ¹
- *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them* by Schwartz, D.L., Tsang, J.M. and Blair, K.P. ²

Before diving into the three approaches, I discuss the cognitive process of learning. This background will help you understand why some teaching strategies are effective, as well as providing with a framework for you to evaluate teaching strategies that you might encounter in the future.

3.1 What does learning really mean?

Activity Throughout your academic journey, has the meaning of learning changed for you? What does it mean for you to *learn* a data science concept, such as cross-validation¹?

¹ James, G., Witten, D., Hastie, T. & Tibshirani, R. (2013) *An Introduction to Statistical Learning: with Applications in R* Springer New York, NY.

You probably notice that learning happens at several levels. At the beginning, you learn what cross-validation *is*, then you learn how to *implement* it in a statistical software, and afterwards you may *apply* it in a project. You might *decide* that standard cross-validation does not apply because your data form a time series, so you searched and found one potential approach called “evaluation on a rolling forecasting origin” ³. These different *cognitive processes* proceed from lower to more advanced levels. During graduate school, you may consider that you have understood a concept if you are able to *teach* it to someone else, or that you are able to connect it with other domains. These are the *human dimension* of learning.

3.1.1 The cognitive process of learning

In this section, I describe the cognitive process of learning through Bloom’s taxonomy, which is a widely adopted framework to articulate educational goals in terms of cognitive activities. The original Bloom’s taxonomy was published in *Taxonomy of Educational Objectives* (1956) ⁴. We will instead focus on the revised taxonomy, published in the book *Taxonomy of Educational objectives: the classification of educational goals* (2021)⁵.

¹ Ambrose Susan A., Bridges Michael W., DiPietro Michele, Lovett Marsha C., and Norman Marie K. *How Learning Works: Seven Research-Based Principles for Smart Teaching*, volume 1 st of *The Jossey-Bass Higher and Adult Education Series*. Jossey-Bass, 2010

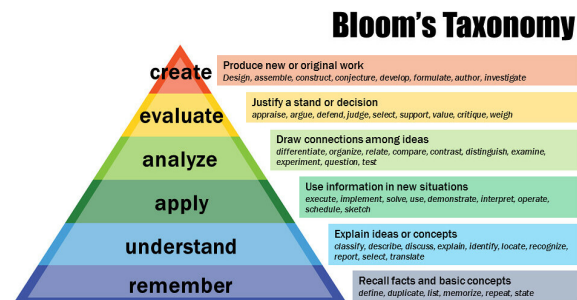
² D. L. Schwartz, J. M. Tsang, and K. P. Blair. *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them*. W W Norton & Co., 2016

³ Rob Hyndman. Cross-validation for time series, 2016

⁴ Patricia Armstrong. Bloom’s taxonomy. <https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/>, 2010. Center for Teaching, Vanderbilt University

⁵ *A taxonomy for learning, teaching, and assessing: a revision of Bloom’s taxonomy of educational objectives*. Longman, New York, complete edition, 2001

The revised taxonomy categorizes cognitive activities of learning into six levels: remember, understand, implement, analyze, evaluate, and create (see Figure 3.2). I briefly describe each one below, and you can find more details from the book.



- When you **remember**, you are able to retrieve information from long-term memory. The information can be factual, conceptual or procedural. For instance, you might remember the names of iconic impressionist paintings (factual); you may recall that the sample mean converges to a normal distribution as sample size increases (factual); or you might remember the steps to carry out a nonparametric bootstrap (procedural).
- When you **understand**, you are able to connect current knowledge with previous knowledge. For instance, you may notice that binomial distribution is an example of sum and thus also approaches a standard normal distribution when appropriately standardized. You can represent information in different forms; for instance, you can sing a tone when you see a note, or you can explain photosynthesis using both chemical equation and a diagram. You are able to provide examples or classify different instances; for example, you will can classify paintings into their corresponding art movements. You are also able to explain and troubleshoot.
- When you **apply**, you are able to execute a procedure by following previous examples, and you are able to choose a procedure when it is appropriate.
- To **analyze**, you are able to differentiate steps in a procedure or an argument. You can organize materials into a coherent structure, and you are able to distinguish the point of view underlying a line of reasoning from the supporting arguments.
- When you are able to **evaluate**, you can check logical inconsistencies and critique the effectiveness of a given method.

Figure 3.1: The revised Bloom's taxonomy is often represented as a pyramid, with the lower level process on the bottom and the higher level processes on the top.

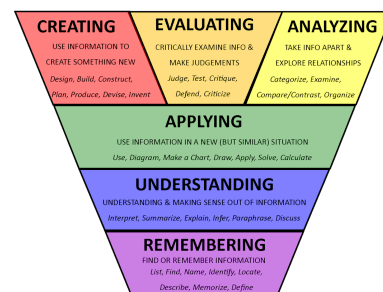


Figure 3.2: Higher level cognitive processes are sometimes represented without hierarchy.

- When you **create**, you can represent a problem, generate a solution, lay out steps to implement your approach and execute the steps.

Activity Pick a data science concept that you want to teach DSSG fellows (you can choose a familiar topic if you do not need to prepare a tutorial).

1. How can you assess if fellows are able to understand this concept? What about if they are able to evaluate a related procedure?
2. Write down three learning objectives. A learning objective is something fellows will be able to do by the end of your tutorial.¹ Your lesson can have multiple learning objectives, spanning multiple cognitive activities. For example, “fellows will be able to construct a logistic regression model for binary response data, make inference for model parameters and predict odds at a given observation.”

¹ You may also want to determine how well fellows know about a topic before your tutorial and design your lesson with that in mind.

3.1.2 *The holistic approach to learning*

Bloom’s taxonomy focuses on the cognitive aspects of learning, whereas Fink’s learning objective, formulated in the book *Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses*⁶, takes into account several other aspects.⁷ Fink categorizes learning objectives into six groups; besides the cognitive processes described in Bloom’s taxonomy (corresponding to the first two groups — foundational knowledge and application), it also points to students’ development in other dimensions. These four categories are:

- *Learning how to learn*: students are able to (1) reflect on their own learning (2) engage in a specific inquiry (3) question how knowledge is constructed and (4) become self-directed learners.
- *Integration*: students are able to connect ideas in different disciplines, contexts, and realms of life. For instance, students are able to question the statistical uncertainty in a statement, or evaluate data visualizations they see in a news article.
- *Human dimension*: For example, students acquire a better understanding of themselves, learn to contribute to the work of a team, to become an effective leader, or to live with ethical principles. In the context of DSSG, they may find that they enjoy learning with

⁶ L. Dee Fink. *Creating Significant Learning Experiences*. John Wiley & Sons, Incorporated, 2nd edition, 2013

⁷ Fink characterizes a “significant learning experience” as one where students are engaged, and has the potential to improve their lives in some important ways.

students from diverse backgrounds and they appreciate different perspectives.

- *Caring*: students may become excited about a specific topic, find new interests or values, or become committed to a certain standard. For example, they may become interested in applying data science to enhance the well-being of others, or committed to ethical problem solving and reproducible analysis.

Fink's taxonomy describes learning as a *developmental process*, that involves both intellectual development, as well as changes in behavior, belief, and attitude. Learning "is a developmental process that intersects with other processes in a student's life, and students enter our classrooms not only with skills, knowledge, and abilities, but also with social and emotional experiences that influence what they value, how they perceive themselves and others, and how they will engage in the learning process."⁸

⁸ Ambrose Susan A., Bridges Michael W., DiPietro Michele, Lovett Marsha C., and Norman Marie K. *How Learning Works: Seven Research-Based Principles for Smart Teaching*, volume 1 of *The Jossey-Bass Higher and Adult Education Series*. Jossey-Bass, 2010

Activity Connect your big dream for the fellows to Bloom's and Fink's learning objectives. Can you formulate three learning goals for each fellow? As an example, you might want them to be able to "formulate a statistical model and evaluate its appropriateness in a given situation", or "present their results clearly, concisely and confidently".

Now that you have identified learning goals for each fellow, I describe three approaches you can use to help fellows achieve their goals.

3.2 Encouraging peer learning

Fellows work in groups to tackle a complex problem during DSSG. The *collaborative* nature of this experience provides a great opportunity for them to learn from each other. Below are a few suggestions to support "peer learning". Why do these activities enhance fellows' learning?

3.2.1 Examples of peer learning

Peer feedback During team meeting, you can dedicate some time for fellows to ask each other questions or give feedback. You can ask fellows to review each other's code, and suggest a list of dimensions to examine. For example: Do you notice any errors? Is the code properly documented? How would you improve this piece of code? What did you learn?

Peer teaching Identify for each fellow one area that they are strong in and ask them to teach others.⁹ You can also ask fellows to explain their approaches to each other.

Team work You can ask fellows to work together on a complex task. For example, each fellow can explore one data set, implement one model, or come up with one way to evaluate a model.¹⁰

3.2.2 What is peer learning?

Peer learning is an instruction approach where students work in teams to accomplish a common goal. The team involves five elements: positive interdependence; individual accountability; face to face promotive interaction; appropriate use of collaborative skills; group processing¹¹. For instance, students may work on a challenging problem together during a workshop. Before the workshop, they are asked to brainstorm individually; during the workshop, they discuss their solutions, ask clarifying questions and provide feedback to each other. With the guidance of an instructor, they devise a solution to the problem as a group. After the workshop, they might be asked to answer a short quiz to assess their individual understanding of relevant concepts.

Here, I adopt a more general definition of peer learning as any activity where students help each other to learn. The examples we provided before were beneficial to learning because they engage higher level cognitive activities. For example, when students elaborate an approach, they need to retrieve information from memory, connect ideas and explain their reasoning.¹² Peer learning also helps students to build a community of learners. West and Williams (2007) provides one definition of a learning community through four aspects: access (readily accessible to each other), connectedness (sense of belonging, trust and interdependence), shared common purpose towards education and function (such as shared practice and class time)¹³. Zhao and Kuh (2004) observed that students who engaged in a learning community gains more knowledge and competence, are more likely to engage with faculties and are overall more satisfied with their college experience¹⁴. Research has also shown that students experience more learning gain when engaged with a diverse perspective (See Chapter L in *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them*).

Activity Design one activity for your project team that is centered around peer learning.

⁹ You may also want to encourage them to reflect on their strength themselves.

¹⁰ The key to successful team work lies in choosing a task that requires team work, setting up norms, explicitly asking students to share and listen, to make sure their tasks are interdependent while at the same time fellows are responsible for their individual piece of the work (See Chapter L in *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them*).

¹¹ Richard M. Felder and Rebecca Brent. Cooperative learning. In Patricia Ann Mabrouk, editor, *Active Learning: Models from the Analytical Sciences (ACS Symposium Series, 970)*, chapter 4. Washington, DC: American Chemical Society, 2007

¹² Chapter T in *The ABCs of How We Learn: 26 Scientifically Proven Approaches, How They Work, and When to Use Them* describes the benefits of explaining and Chapter 4 in *Small teaching: Everyday Lessons From the Science of Teaching* (2016) describes the benefits of connecting ideas.

¹³ Richard E. West and Gregory S. Williams. "I don't think that word means what you think it means": A proposed framework for defining learning communities. *Technol. Res. Dev.*, 65(6):1569–1582, 2017

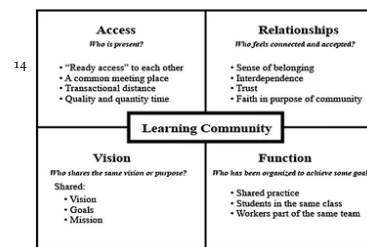


Figure 3.3: Characteristics of a learning community defined in West and Williams (2017).

3.3 *Developing Meta cognition*

Meta-cognition is the process of *reflecting on and directing* one's own thinking¹⁵. Ultimately, we want fellows to become independent data scientists who are able to assess the need of the community partner and carry out a complex project. In this section, I will focus on two aspects of meta-cognition: evaluating one's learning and solving a problem.

¹⁵ National Research Council. *Knowing What Students Know: The Science and Design of Educational Assessment*. The National Academies Press, Washington, DC, 2001

3.3.1 *Evaluate one's learning*

Does it every happen to you that you sit down to implement a clustering algorithm that you thought you knew well and all of a sudden unanswered questions appear? Indeed, we often become aware if we know something well when we try to retrieve information. There are many things you can do to help fellows evaluate their learning. Here are some starting ideas and I encourage you to develop more approaches.

- Probe fellow's knowledge by asking them to explain what a particular statistical method is and how it works.
- Ask fellows to document their own work and thinking process.
- Ask fellows to ask each other clarifying questions.

3.3.2 *Meta-cognition during problem solving*

Consider the problem of predicting treatment effect on patients, I describe five steps involved in solving this problem and how you can guide fellows to reflect on each step. These steps are based on Chapter 7 in *How learning works: Seven Research-Based Principles for Smart Teaching* and the article *A detailed characterization of the expert problem-solving process in science and engineering: Guidance for teaching and assessment*¹⁶.

Framing the problem Before jumping into finding solutions, fellows need to know precisely what is the problem, what is the goal, and what are some criteria to determine if their solution is successful.

At this stage, we can ask fellows what is the goal of their task and what steps they need to carry out. A successful problem framing might look like "I want to predict a patient's blood pressure during the next twenty-four hours after taking the medication. I choose to look at the next twenty-four hours because that's the time period before they take their next medication. I especially care about how well I am able to capture a hypertensive crisis because of the consequence of missing this event."

¹⁶ Argenta M. Price, Candice J. Kim, Eric W. Burkholder, Amy V. Fritz, and Carl E. Wieman. A detailed characterization of the expert problem-solving process in science and engineering: Guidance for teaching and assessment. *CBE Life Sci. Educ.*, 20(3), 2021

Planning the approach Next, fellows need to identify appropriate procedures and outline a path towards a solution. This step may involve several iterations, as they may start with one approach, evaluate whether it works, and then experiment with another approach until they decide on a promising method.

At this stage, you can ask them to describe what procedures they plan to use and why they make these selections. You can also demonstrate your thinking process, for example, “I will first simplify the problem — it might be easier to predict if one person would experience hypertensive crisis or not. One way to do that is by using responses of similar individuals. For example, I can use clustering and if I do that, I will first need to compute similarity between each individual and then I need to choose one specific clustering method. How do I determine similarity between individuals? Perhaps I can use the Euclidean distance, then I can include all of the variables. However, a drawback is that Euclidean distance treats different variables but they may have different importance. I may deal with it by... The different clustering methods I can use are ...”.

Identifying roadblocks and gaps Next, fellows need to identify gaps in their knowledge and skills. For example, they might need to use a software developed by other researchers, read some literature, or clarify some concepts with the project partner. You can ask fellows to describe what challenges they might encounter and how they can address them. An example of such challenges might be “I need to ask our community partner which features they think are relevant and how to characterize similarity between patients.”

Monitoring progress After planning the procedure, fellows will implement their plan. At this point, you can encourage them to monitor their own progress. For example, you can ask them to connect what they are currently doing with their plan, what new challenges they encounter, and what additional information they might need. For example, they might notice that several variables are missing, and therefore they need to devise a plan to impute these variables.

Adjusting one's approach Finally, fellows need to measure the performance of their solution, interpret their results and reflect on how they can improve or adjust their approach. You can ask them to explain their findings and conclusions. You can ask them to describe how well they think their method is working, and which adjustments they might consider. You can also ask them to connect their progress with the overall project goal. A reflection at this stage may be “the clustering approach gives an accuracy of x%. It's particularly effective

at identifying occurrence of hypertensive events because the sensitivity is high. However, this approach does not use the information from individuals who are not similar. The next step is ...”

Activity Write down one question to ask fellows during each step in their problem solving. Ask these questions during your team meeting and take notes of a few of their responses. Do you notice any change in how fellows approach a problem during the course of DSSG?

3.4 Incorporating active learning

Active learning is an instructional method where students are engaged in the learning process, in contrast to the traditional learning approaches where they passively listen to an expert¹⁷. Students may work in a group, e.g., discussing answers with a partner¹⁸, but they can work individually, e.g., thinking about an answer on their own.

Active learning benefits students in many ways. First, it stimulates higher level cognitive process. For example, Freeman et al. (2014) showed that active learning can be used to teach critical thinking skills¹⁹. In this study, students were asked to take measurements in two different ways and compare the results. Then, they were told to devise a plan to improve measurement quality and carry out the revised measurement. They were then asked to determine whether their data agrees with a model, and if not, whether it is because of data quality or model accuracy, and how would they improve measurement in the first case and how would they carry out new experiment in the second case. By practicing critical thinking, students learned to think like a scientist, who routinely compare results with a model and decide whether to question their measurement or the model. Researchers found that not only is this approach effective, but for some students, the effect persists when they are no longer asked to compare results between measurements.

Active learning also helps to increase students’ self-efficacy, motivation, and sense of belonging. This is especially true for students from underrepresented minority (URM) groups, who tend to learn better when they have higher self-efficacy²⁰.

In fact, the entire DSSG program is an active learning experience where fellows are engaged in their learning! That’s why it’s particularly important for you to encourage fellows to work together and discover solutions themselves. In the remainder of this section, I will explore active learning in the narrower setting when you are explaining a new concept.

¹⁷ Michael Prince. Does active learning work? a review of the research. *J. Eng. Educ.*, 93(3):223–231, 2004

¹⁸ Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. U.S.A.*, 111(23): 8410–8415, 2014

¹⁹ N. G. Holmes, C. E. Wieman, and D. A. Bonn. Teaching critical thinking. *Proc Natl Acad Sci U S A.*, 112:11199—11204, 2015

²⁰ Cissy J. Ballen, Carl Wieman, Shima Salehi, Jeremy B. Searle, and Kelly R. Zamudio. Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE Life Sci. Educ.*, 16(4), 2017

3.4.1 Examples of active learning

Below are a few examples of learning activities, and I encourage you to reflect on an effective learning experience you have had in the past.

Activity Think about a learning activity you have participated in, what did you do? Was it effective? How would you improve it?

Are data i.i.d.? This was an activity my professor designed for a course on statistical inference. At the start of the lecture, he handed out pieces of paper with sequences of 1s and 0s written on it. Then he asked “Is this sequence of numbers i.i.d. with probability 0.5 being 0 or 1?”. We were given 5 minutes to think and then he asked some of us to share our answer to the entire class. After several of us explained our reasoning, he explained that all of the numbers are 0 or 1 with probability one half. However, the numbers are not generated independently because they are more likely to be the same as the preceding number. One way one can discover this is by counting the number of 0s before encountering a 1.

How much of the Earth is water? In Section 9.3.3 of *Teaching statistics: a bag of tricks*²¹, the authors described the following in-class activity. Students are asked how they would estimate the proportion of earth covered by water. After they mention a few approaches, the instructor would take out an inflated globe and ask students to toss it around, each time, their finger would touch one point on the globe and they are asked to shout out if their finger touched land or water. The instructor would record the answers and then ask students to estimate the proportion of water as well as provide a confidence interval. Finally, the instructor ask students how they would take random samples from a globe.

Alien attack This example is from the article *Why we are teaching science wrong, and how to make it right*²². During a neuroscience class, the instructor asks students to answer the following question and explain their reasoning: You’re innocently walking down the street when aliens zap away the sensory neurons in your legs. What happens? (a) Your walking movements show no significant change. (b) You can no longer walk. (c) You can walk, but the pace changes. (d) You can walk, but clumsily.

3.4.2 How to incorporate active learning?

As you can see from the examples, you can incorporate active learning through designing an activity in which fellows can participate, or

²¹ Andrew Gelman and Deborah Nolan. *Teaching Statistics: A Bag of Tricks*. Oxford University Press, 2nd edition, 2017

²² M. Mitchell Waldrop. Why we are teaching science wrong, and how to make it right. *Nature*, 523(7560):272–274, 2015

through asking a thought-provoking question.

In the article *Learning by Doing*, the authors offer several simple ways to integrate active learning in your teaching²³ (the following is an excerpt from the article):

1. Give the students something to do (*answer a question, sketch a flow chart or diagram or plot, outline a problem solution, solve all or part of a problem, carry out some formula derivation, predict a system, interpret an observation or an experiment result, critique a design, troubleshoot, brainstorm, come up with a question, ...*).
2. Tell them to work individually, in pairs, or in groups of three or four; tell them how long they'll have (anywhere from 10 seconds to two minutes); and turn them loose.
3. Stop them after the allotted time, call on a few individuals for responses, ask for additional volunteered responses, provide your own response if necessary, and continue teaching.

The article also describes the classical think-aloud pair problem solving (TAPPS) approach: students are asked to work on a problem in pairs, one of them explaining a solution and the other student ask questions. After sometime, you can ask students to share their answers, and you can provide your solution if necessary. Then, you can ask students to switch roles.

Now that you have seen a few examples of active learning, I invite you to design one activity for your tutorial.

Activity Design one activity for your tutorial session. What's the goal of this activity? Write down a prompt, what should fellows do during the activity?

²³ Richard M. Felder and Rebecca Brent. Learning by doing. *Chem Eng Educ*, 37 (4):282–283, 2003

4

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5

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