MAPPING 'ENGINEERING FOR GOOD' CAREER PATHWAYS: EXAMPLES FROM NORTH AMERICA

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Executive Summary

Through a research collaboration between Engineering for Change and the Colorado School of Mines, we have developed a career map for engineers trained in North America and who desire to work in Engineering for Good (EfG). EfG is defined as "the practice of prioritizing doing good over more traditional engineering urgencies such as cost, technological efficiency, and innovation" and includes work in international and domestic community development, disaster response, and poverty alleviation.[1] As more and more academic programs related to EfG are being offered in North America, early-career engineers and engineering students are eager to start their careers in EfG, but often find few resources to guide their job search.[2] There is a growing demand for engineers committed to sustainable humanitarian practices, with a growing population of well-trained graduates prepared to take on their roles. To help these two groups come together, a well-developed map can be a tool that allows students to align their professional careers with their aspirations.

Through desk research and interviews with 8 EfG engineers, we have developed the three-stage EfG Career Map that shows how engineers can progress from earning a Bachelor's degree (Stage One) to finding a career in EfG (Stage 3). In Stage 2, we have identified 4 common early-career experiences: field experience, higher education, traditional engineering experience, and intern/volunteer experience, as well as common skills to develop in one's early-career. In Stage 3, the map shows EfG example roles and organization types to provide reference in this amorphous, evolving area of engineering.

Concepts like considering what it means to be an engineer in terms of the 'whole self' as well as planning one's career path under the principle of 'structured serendipity' emerged from our collective data set. These highlighted ideas speak to the value of personal, emotional, and creative skills for finding a fulfilling career in EfG. Expanded on below are ways a student or professional can pragmatically apply these themes to developing their career for doing good.

We recommend that additional research be completed to better understand the characteristics of established EfG career roles and the types of organizations involved in EfG, as well as how different types of engineering majors may affect the future EfG roles available to an engineer.

[1] Kleine, M. S., Lucena, J., 2021, "The World of "Engineering for Good"," Middle Atlantic ASEE Section Spring 2021 Conference.
[2] Peiffer, E., 2020, "State of Engineering for Global Development - United States and Canada," Engineering for Change, https://www.engineeringforchange.org/wp-content/uploads/2020/02/State-of-EGD-North-America-Full-Report_updated2.2020.pdf.

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Careers in Engineering for Good

Over the last decade, there has been a dramatic increase in the number of academic programs in North America that offer a new type of engineering.[3] The focuses of these programs range from community service[4] and global development,[5] to peace engineering[6] and social justice[7]. Casting a wide net to include all socially-oriented engineering, Juan Lucena and Marie Stettler Kleine at the Colorado School of Mines have used the term "Engineering for Good" (EfG) to mean "the practice of prioritizing doing good over more traditional engineering urgencies such as cost, technological efficiency, and innovation."[8] Researchers have studied EfG within the academic space[9] and there are papers[10] and conferences[11] that discuss specific case studies of EfG work. However, our research focuses on defining the early EfG career paths taken by engineers who have been trained in North America. We hope this career map can support these engineers in pursuit of their career goals.

Exploring EfG Careers

Information for this research project was gathered primarily through interviews, with additional supporting information gathered through desk research. During initial desk research, we developed a list of over 100 organizations in which engineers might work or volunteer in EfG roles. For the purposes of this research we defined an engineer as someone who had received a degree at any level in engineering. After finding the organization, we confirmed they hire engineers (or bring on volunteer engineers) by checking their website and employee profiles on LinkedIn. This process helped provide a context for what a job search in EfG might look like for an engineer, as well as providing information relevant to the career map such as example roles and organization types. Other initial research included common career map formats,[12] how to define an emerging field like EfG[13] and what type of work could be included in EfG.[14] Our definitional research informed the boundaries placed around our career map and also informed our selected pool of interviewees.

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[3] Peiffer, E., 2020, "State of Engineering for Global Development - United States and Canada," Engineering for Change, https://www.engineeringforchange.org/wp-content/uploads/2020/02/State-of-EGD-North-America-Full-Report_updated2.2020.pdf.
[4] "Welcome to EPICS", Purdue, September 22, 2021, https://engineering.purdue.edu/EPICS.
[5] "Mortenson Center in Global Engineering", University of Colorado Boulder, September 22, 2021, https://www.colorado.edu/center/mortenson/.
[6] "Peace Engineering Master's Degree Program", Drexel, September 22, 2021, https://drexel.edu/engineering/academics/areas-of-study-programs/peace-engineering/.
[7] "Social Justice Focus", Loyola University of Chicago, September 22, 2021, https://www.luc.edu/engineeringscience/curriculum/socialjusticefocus/.
[8] Kleine, M. S., Lucena, J., 2021, "The World of "Engineering for Good"" Middle Atlantic ASEE Section Spring 2021 Conference.
[9] Campbell, R., Wilson, D., 2011, "The Unique Value of Humanitarian Engineering," 2011 ASEE Annual Conference & Exposition.
[10] Israsena, P., Isaradisaikul, S., Noymai, A., Boonyanukul, S., Hemakom, A., Chinnarat, C., Navacharoen, N., Lekagul, S., 2013, "Developing an Appropriate Digital Hearing Aid for Low-Resource Countries: A Case Study", The Scientific World Journal, 2013, pp. 549486.
[11] "IEEE Global Humanitarian Technology Conference (GHTC)," IEEE, September 24, 2021, https://ieeeghtc.org/.
[12] "Compass Map", Institute for the Future, September 22, 2021, https://www.iftf.org/fileadmin/user_upload/images/More_Projects_Images/CompassMap.jpg.
[13] J. Schneider, J. Lucena, and J. A. Leydens, 2009, "Engineering to Help," IEEE Technology and Society Magazine, 28, pp. 42-48.
[14] Carreira, O., 2020, "Defining Transcreation from the Practitioners Perspective."

Interviews

Interviewee Backgrounds

Using information from the desk research, we developed a list of interviewees who represent the experiences of engineers that either work or volunteer on EfG projects (i.e., Practitioners) as well as the perspectives of EfG engineers who continue to define, develop, and connect the field of EfG (i.e., Leaders). One person can play multiple roles however, like Leaders who do work on EfG projects as well as a Practitioner that participates in field-defining work. Practitioner interviewees bring on-the-ground perspectives to EfG careers, while Leaders bring a bird's-eye-view of the field of EfG, including how they see the development of the field and trends in EfG. The sample of interviewees was intentionally diverse in gender, age, years of experience, and areas of expertise as shown in Table 1 below. All interviewees received one or more degrees in engineering and at least one of those degrees was from a school located in North America since the EfG Career Map is intended to be used by engineers trained in North America.

Table 1. Background information for Interviewees.

Category	Interviewee Information
EfG Role	5 EfG Leaders, 3 Practitioners
Gender	5 Men, 3 Women
Estimated Age	Range: Late-20's to over 65 years old Average Age: Approx. 45 years
Years of EfG Experience	Range: <10 years to 20+ years Average Experience: Approx. 14 years
EfG Sectors (for Practitioners)	WASH, Energy, Waste Recycling

Interview Procedures

An interview guide was developed based on our interviewee list and our draft concepts for a career map[11]. The interview guides were developed using "The Ethnographic Interview" by Spradley[15] as a guide, and were conducted in August 2021. The guiding research questions were "what are the career paths in EfG?" and "what are the motivations of engineers in EfG, and what is the impact of their work?" Specific interview guides were personalized for each interviewee based on their background and expertise. Human subjects research protocols were followed in accordance with policies at the Colorado School of Mines which conform to the Federal Policy for the Protection of Human Subjects (45 CFR part 46) and the principles described in The Belmont Report. Audio was recorded during interviews and later transcribed through software and manual methods. The interview data was then coded based on trends observed in the data and categories of content utilized in the EfG Career Map. Lastly, during the development of the EfG Career Map, a recent graduate of an EfG Masters program provided user feedback to help ensure that the map is a tool that would help early-career engineers pursue a career in EfG.

[15] Spradley, J., 2016, *The Ethnographic Interview*. Waveland Press.

Engineering for Good Career Map

Using the data derived from desk research and interviews, we developed the EfG Career Map shown in Figure 1 on the next page. The EfG Career Map is intended to provide guidance to an engineer who wants to progress from earning their Bachelor's degree to having a career in EfG by showing common and recommended early-career components for engineers in EfG. The map is not meant to be all-encompassing, nor is it meant to suggest that all components are necessary to have a career in EfG. Below is an explanation of each step, important notes from the data regarding components of the career map, and an example career path.

Step 1 - Bachelor's degree

Since this career map is designed for engineers who have earned a degree focused on engineering from an institution in North America, we have chosen to start the map with a Bachelor's degree. Additionally, all of our interviewees began their EfG careers by earning a Bachelor's degree with an engineering major. Based on our desk research, almost all EfG engineers start their career paths with a Bachelor's degree with an engineering major however, someone could transition into engineering with a Master's degree and have received a Bachelor's degree that was not focused in engineering. For example, we did notice some EfG engineers who had bachelor's degrees in the sciences or social work, but then they studied engineering in Master's or PhD programs.

Step 2 - Common Early-Career Options

In an EfG engineer's early-career, our research shows that there are four common experiences: field experience, higher education, traditional engineering experience, and internship/volunteer experiences. Additionally, there are a number of skills that the interviewees recommended or found helpful for EfG engineers to acquire during their education and early-career. In each common experience, we have included three pieces of data: opportunities, value, and quotes. The opportunities list shows types or examples of organizations that may provide an opportunity to achieve this experience, the Value statement explains why this experience can help develop an EfG engineer's career path, and the quote section are statements from our interviewees about this common experience.

Step 3 - Common Established Career Options

The third step in the career map shows a list of example roles and organization types in which an EfG engineer may work. The diversity of example roles shows that engineers in EfG should also look for roles with titles other than strictly "engineer". These example roles can be used as keywords when conducting a job search. The organization types are meant to provide a broad understanding of the variety of entities that an engineer may work for or volunteer with in EfG. In each organization type, we have included a couple examples of this type of organization.

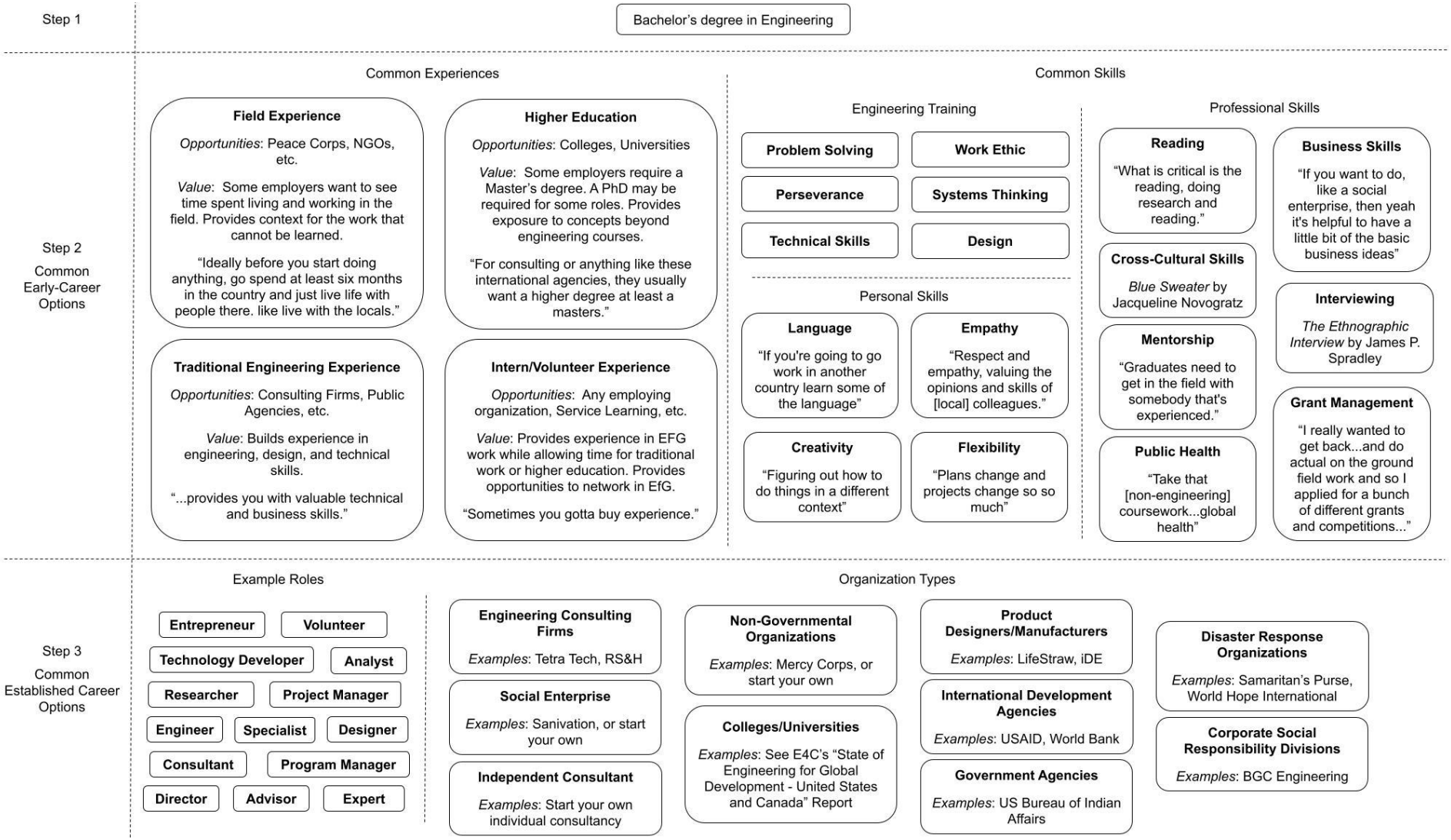

Figure 1. Engineering for Good Career Map

Important Map Notes

Common Experiences

The Practitioners we interviewed strongly emphasized the importance of spending a prolonged time living as a part of a community in the region in which an engineer wants to work. Many interviewees also noted that many EfG organizations will require a Master's degree or higher. Therefore, the most commonly recommended experiences are field experience and higher education. All of the Practitioners interviewed also had some amount of traditional engineering experience, although none of the Practitioners specifically recommended pursuing traditional engineering experiences. One EfG Leader did recommend spending time in traditional engineering, while another EfG Leader stated that time in a traditional engineering role may be necessary for financial reasons like paying off student loans. All of the Practitioners we interviewed had volunteered their engineering skills on an EfG project, and two specifically recommended it.

Common Skills

Some of the most commonly recommended skills were creativity and problem solving. One interviewee commented on these skills by saying, "Flexibility, that openness to others asking questions and questioning the direction is not cultivated through engineering curriculum". The skills listed in the common skills section provides a representative example of the common skills that respondents prioritized. However, some skills are more relevant to certain careers. One example is that business skills are more helpful for EfG engineers who want to be entrepreneurs or work in market-based development interventions. Many Practitioners noted the importance of interviewing and grants to their work, and as such were added as common skills. Regarding grants, it was interesting to note that two Practitioners found grants to be limiting to their work because it determined a project focus, which was not always ideal, in the opinion of the EfG engineer. However, another Practitioner had the opposite perspective, and found freedom in their projects from being able to develop their own project proposal, then seek grant funding for that project.

Future Research

Additional research should be completed to better understand the characteristics of the example roles and organization types listed in Step 3, as well as how training in different engineering disciplines (e.g. civil, mechanical) may affect the future EfG roles available to an engineer. The career map could be enhanced further with data from additional practitioner interviews as well. The Colorado School of Mines plans to continue aspects of this research while focusing on additional characteristics of Engineering for Good.

Important Trends

EfG Motivations

Many interviewees spoke about why they pursued an EfG-based career after their education. "I wanted to be a global professional to help and make change happen" said one interviewee, while noting their desire to, "move theory into practice." The Practitioners interviewed noted the meaning they found in EfG work and that the draw "to help" motivated them to pursue EfG work. One interviewee shared their experience with and support of personal check-ins during their undergraduate development. They encouraged students to ask themselves, "what is your role in enacting change?" as they progressed through their education. While some EfG engineers become interested in EfG during their undergraduate education, all three of the Practitioners interviewed did not realize their passion for EfG until after completing their Bachelor's degrees. For example, one Practitioner realized that they wanted to pursue EfG work after spending several years as an engineering consultant.

EfG compared to Traditional Engineering

The data received through our interviews was surprisingly consistent considering that a diverse group of EfG Practitioners and Leaders were selected. For example, all of the Practitioners that were interviewed stated that the engineering work in EfG and traditional engineering are very similar, but the problems that are being solved have added social components and the work is more meaningful. One interviewee said, "the actual engineering work can be similar" and "my work in [a low income country] is a lot more rewarding for sure, it has a lot more meaning." The same interviewee made another observation that was repeated by others regarding the similarities between EfG and traditional engineering when they stated that, "you don't have to be an expert in business or in anthropology, interviewing, economics, or whatever, but having some exposure to these other fields beyond just the super technical engineering definitely helps when you're trying to develop a product or develop a technical solution to a problem...even in America." The idea that "other fields" and skills that are not commonly learned through traditional engineering training but are very important in EfG work was noted by many interviewees. The interviewees did not use the same language when referring to the skills that they felt were outside of traditional engineering training, so we created the categorical terms of "personal skills" and "professional skills" to organize the skills within the EfG Career Map.

While professional and personal skills were mentioned as being important, traditional engineering skills were not left out as many interviewees mentioned the importance of strong engineering skills. When referring to this category of skills, interviewees used phrases like "technical skills" and "engineering skills." We represented the specific skills that interviewees attributed to their traditional engineering training and felt were important to their EfG work under "engineering training" in the common skills subsection section in Figure 1. One interviewee felt that EfG historically had been overly focused on traditional engineering skills and ignored the professional and personal skills, but that recently EfG has over-corrected and had started to neglect the importance of strong engineering skills. After having explained the importance of professional and personal Skills, one interviewee wanted to affirm the importance of strong engineering skills and stated, "you actually do have to have a baseline of skill to achieve things." This interviewee was explaining that to do EfG, engineers must have a baseline of engineering skills to "achieve things" or perform the engineering work.

Engineering Specialties

Only one interviewee talked about the differences between different types of engineering majors and their impact on an engineer's EfG work. This interviewee commented that because they had studied mechanical engineering, they were not sure where they would fit into EfG. When asked if the type of engineering degree (e.g. civil, mechanical) affects an engineer's ability to work in EfG, the interviewee responded "I think there are applications for all the different engineering, but, especially you should also learn about design and working with the community and like really designing for or designing with the users." Each of the three Practitioners interviewed had unique engineering majors for their Bachelor's degrees which shows that it is possible for engineers from a variety of specialties to participate in EfG work.

The "Whole Self"

Three Leaders in this field mentioned the importance of looking at one's career through the lens of the 'whole self' as a way to better understand how their professional identity pairs with their personal lives. One interviewee listed different aspects of an engineer that are typically outside traditional technical skills, "it's the ideas, emotions, values, principals, mindsets, ways of looking at the world". Their statement sheds light on the areas we typically do not consider within the demarcation of the qualities in a good engineer. However, becoming aware of these qualities can help an early-career engineer assess where their interests lie, and therefore enable them to

apply their skills in a field where they are most fulfilled, and effective. One Leader discussed a specific tool that engineers can use to better understand their skills in the form of questions like, “Where do you see yourself fitting in? Where are your skills best applied?”.

The concept of the whole self emerges as a guiding metric throughout one’s career, and can be used to assess the purpose of an engineer’s work and how it serves the engineer, their interests, and the world. To speak to this concept a bit more, an interviewee provided some advice on how to align an engineer’s work to their passions, “Work on a project because it aligns with your purpose, not your major”. During the course of an engineer's educational and professional career, the particular major or field they’re interested in may shift. To invite opportunities that fit with an engineer’s changing interests, our interviewee suggests avoiding putting oneself in a box defined by one’s major. Seeing oneself as the ‘whole engineer’ provides insight into what type of work is exciting to the engineer, and allows one to develop their skills for a passionate career.

Example Career Path

Figure 2 is an example career path that shows one way that an engineer could build a career in EfG that was shared by an interviewee. The interviewee suggested that after an engineer earns their Bachelor’s degree, they could join the Peace Corps that has a corresponding Master’s degree program where an engineer can possibly earn credit or a scholarship towards their Master’s degree. Then after earning a Master’s degree, the engineer can work for a few years at a smaller non-governmental organization, then join a large multilateral international development agency. The relevant career map components have been highlighted in Figure 2. This example path shows how an engineer can use these common experiences as stepping stones that build common skills which support them in attaining common established career options.

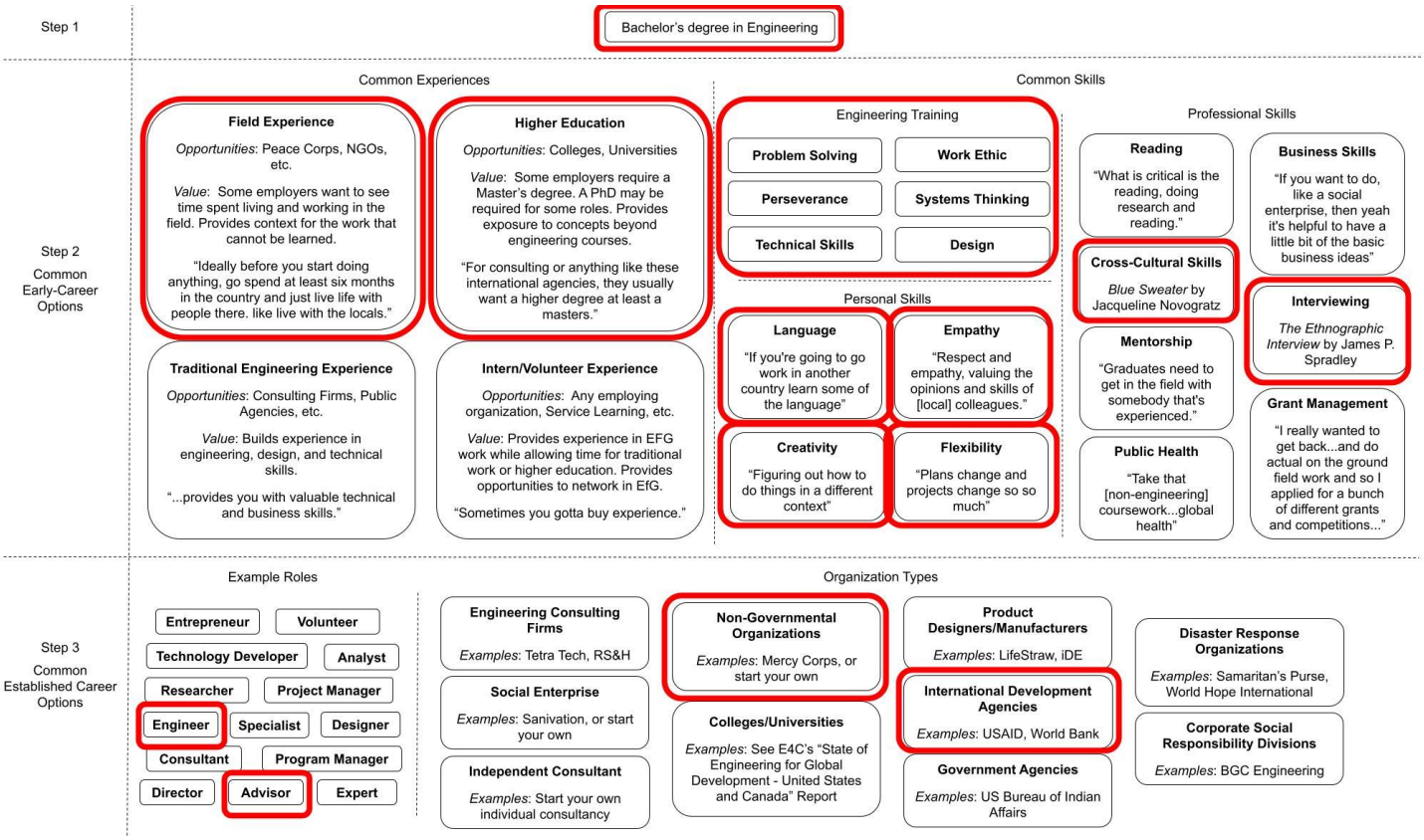

Figure 2. Example Path in the EfG Career Map

Conclusion: "Structured Serendipity"

The EfG Career Map shown in Figure 1 shows 4 common experiences of EfG engineers during their early-careers, during which they acquire a variety of common skills that prepare them for a wide range of EfG career roles. An important and unique insight discovered through the interview data is that career opportunities are often found through a chance opportunity, or as one interviewee called it, "structured serendipity". The concept of structured serendipity has been noted in other fields as well.[16] For example, none of the Practitioners that were interviewed started their EfG careers with a specific path in mind, and they seemed to feel that they got to their current roles by taking one opportunity after another.

The concept of structured serendipity is important to highlight as career paths can often be thought of as linear, planned, and under the control of the professional. Our data shows a more realistic viewpoint where an engineer gains a unique set of skills through their early-career experiences, then finds a role that aligns with EfG work that feels meaningful to them through serendipitous encounters and opportunities. To prepare oneself for these chance connections, interviewees suggest an engineer build a set of skills early through professional and volunteer work that "aligns with your mission." These encounters can include social situations like a conversation on campus, a conference, connections made through professional associations, or a variety of other unpredictable events. The interviewees followed their intuition for interests that guide their professional direction, and further invested their time and involvement as it felt right. The concept of structured serendipity appears in

[16] Race, T., 2012, *Planning and Implementing Resource Discovery Tools in Academic Libraries*, IGI Global, Western Kentucky University, USA, Chapter 9.

the career map through how common skills relate and are codependent upon the common experiences. An engineer seeking an impactful career can invite in the concept of structured serendipity in pursuing experiences that will gain them the necessary skills to take on a fulfilling role in EfG, when one presents itself.

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