Coffee and Engineering Education: Lessons from an Engineering Course on Technology for Coffee Production

Pedro Reynolds-Cuéllar
Center for Civic Media
MIT
Cambridge, USA
pcuellar@mit.edu

Alejandra Villamil-Mejía
School of Architecture and Habitat
Jorge Tadeo Lozano University
Bogotá, Colombia
claudiaa.villamilm@utadeo.edu.co

Alexander Freese Bello
Technology Design Division
C-Innova Innovation Center
Bogotá, Colombia
freese.alex@gmail.com

***Abstract*—In recent decades, engineering education within universities in the United States has shifted towards engaging learners through various forms of applied learning. These models provide an opportunity to connect academia with real-world environments. One connection of particular importance is the one linking engineering education and society: how can engineering education connect learning with some of the most pressing global sustainability challenges we currently face?**

As a result, universities are turning to communities globally in search for opportunities to connect students with sustainability related issues. The appearance of academic offerings including international courses, global exchanges and fellowships abroad among others, are a testament to the efforts within higher institutions to create these bridges. From a scholarly perspective, literature describing these kinds of community-based programs has been on the rise. However, the majority of these programs, and the research surrounding them, are almost exclusively focused on the potential transformation this connection brings to learners, much less on what community-based interaction means for engineering education transformation. This paper is an effort in bridging that gap.

The *"Technology Design for Coffee Production: A Co-Design Experience"*, is a community-based course on technology design and engineering offered to an interdisciplinary group of graduate students, primarily from the Massachusetts Institute of Technology (MIT). The course was facilitated directly from within coffee farms in Colombia in collaboration with local groups over the course of a month. We conclude that three principles are promising for future community-based engineering education offerings: 1) community immersion; 2) positioning local community members as learning instructors; 3) thick contextualization of the engineering design process. We discuss how each of these principles is reflected in the curriculum of the course, and how they were implemented.

Future work includes further examining lessons and expanding them into other engineering education offerings at MIT including a revised second edition of the course to graduate students from all five schools at MIT.

***Keywords*—engineering education, sustainability, coffee production, community-based work.**

I. Introduction

Connecting students with community-based work is not a recent trend in higher education programs in engineering [1], [2], [3]. Through various formats, universities and colleges are integrating a variety of activities allowing students to explore new directions for their academic life and connect newly learned skills with real-world problems. From within academic programs at these institutions, it is now common for engineering, science and design departments to provide course offerings that include elements of fieldwork in cooperation with communities globally [4].

Community-based engineering courses have proven to be effective in enhancing students' learning and motivation [7], [8], [9], as well as in providing opportunities to embed socially oriented aspects such as conflict management and social justice principles into curricula [10]. Our work adds to this literature by providing an account of a community-based course in technology engineering for coffee production at MIT, implemented in collaboration with rural coffee growers in Colombia. These courses have the potential to yield valuable lessons to engineering education. Curriculum changes driven by areas such as humanitarian engineering [5], [6], [11] and service learning [12], [13], [14] are already underway. This paper is an effort in expanding this body of work by presenting an analysis of what we consider useful principles to make community-based courses effective.

Our work innovates within community-based programs in engineering education, by making members of partnering communities act beyond the traditional roles of clients/users [15], [16] or codesigners [17]. Although these categories recognize community stakeholders as possessors of key knowledge and expertise, it does not necessarily position them as deliverers of content in the same way a professor or an instructor is positioned. This paper reviews our experience shifting this power dynamic and reflects on how they affect students.

II. Background

The course is inspired by prior academic offerings. For example, the MIT D-Lab [18] offers courses connecting students with communities across the world, through projects in areas ranging from prosthetic and assistive technology development, all the way to biomass-based charcoal production [19], [20]. The Affordable Design and Entrepreneurship program at the Olin School of Engineering [21], provides a similar offering for undergraduate education with an added focus on entrepreneurship [22]. The d.school at Stanford University also features a course with similar characteristics concentrated in design for extreme affordability [23].

The course connects with a body of work done in collaboration with Colombian rural farmers through the International Development Design Summits (IDDS) program in Colombia [28], [29], [30], [31]. From a theoretical perspective, the course draws inspiration from the Creative Capacity Building methodology [39]. This model describes philosophical underpinnings of the work as well as the reasoning behind active learning approach to teaching.

One particular aspect of the course is its focus on a specific economic sector: coffee. The fact that worldwide, coffee is positioned in the agriculture sector as one of the top traded commodities according to the FAO [24], makes it an interesting context for engineering work. Academic focus on issues surrounding prosperity and sustainability is on the rise. Examples include Ssozi-Mugarura et al. [25] work done in participation with community members in rural Uganda on water management, Capaccioli et al. [26] study on participatory energy infrastructure in the northwestern Italian region, and Siozos study of collective assessment applications for secondary education along with Greek communities [27].

Finally, the course poses an innovative premise by positioning community members as content instructors. This approach is motivated by work showing the benefits of including research participants as active members and contributors of research teams, or what is known as co-research [32], [33]. It builds on literature in the field of Participatory Design pointing to the benefits of this type of dynamic in designing research projects [34], as well as in the production of knowledge through research [35].

III. Technology Design for Coffee Production: A Co-Design Experience

A. Motivation and Intended Learning Outcomes

Every year during the January period, MIT offers a program with for-credit and not-for-credit courses to all undergraduate and graduate students. These classes provide students the opportunity to freely explore other topics beyond their academic requirements. Our course was part of this program, and was offered to students as a not-for-credit subject.

The Intended Learning Goals are for students to leave the course being able to: 1) recognize all stages in the process of small-scale coffee production in a rural region of central Colombia; 2) plan and facilitate design research sessions through fieldwork activities; 3) conduct agricultural processes related to small-scale coffee production; 4) create functional, 1:1 scaled engineering prototypes in collaboration with rural community members; and 5) develop engineering projects that take social, cultural and business aspects into consideration.

B. Structure of the Course

1) Students selection and team formation: The course was designed to cater to advanced degree students in three areas of knowledge: engineering, social sciences and business. Students applied to the course via a survey designed to surface prior collaboration, engineering and communication skills. The selection process included diversity (across multiple vectors), past experiences and interest in the coffee sector as the main variables.

Following the selection process, students were divided into two groups and paired with two rural small-scale coffee-growing collectives. Three to four leading members from each collective, along with two design facilitators, completed each group. Families and neighbors at each community constituted a second layer of support. A map of all these resources was handed over to teams in the form of a social cartography [36].

2) Partner Selection: The course partnered with two coffee farming collectives: De Finca [37], a coffee farming organization from the Guavio Alto community in the Sumapaz region of central Colombia, tasked with "producing and transforming top quality artisanal coffee"; and APRENAT [38], an organization from Central Colombia with the mission to "contribute to the conservation of natural resources, ecological diversity, and the ancestral farming culture in the Tibacuy region". The selection of these partners was based on prior work and research done by the course instructors and focused on identifying collectives with ongoing projects, and interested in collaborating with university students. It included community workshops to map needs and opportunities for projects, collect key information around stakeholders, infrastructure, assets, as well as other relevant information for students. It also included preparations related to room and board, transportation, safety and other logistical details.

Figure 1. Immersion activity, understanding connections between beekeping and coffee production at APRENAT.

3) Curriculum and course stages: The duration of the course was 21 days. This timeline was divided into four stages, most of which included engineering practice activities. Table 1 presents the layout of the curriculum. Although our focus was on hands-on work, we acknowledge that context is key, therefore small part of the beginning of the program was dedicated to expose students the various aspects of small-scale coffee production in Colombia. It comprised four different teaching strategies: a) theoretical and conceptual foundations through visits to organizations, talks and lectures; b) interactive, practical activities to develop fieldwork skills; c) collaborative work activities leading to project formulation and execution; and d) machining and manufacturing activities. These strategies were chosen based on the IDDS program model [28].

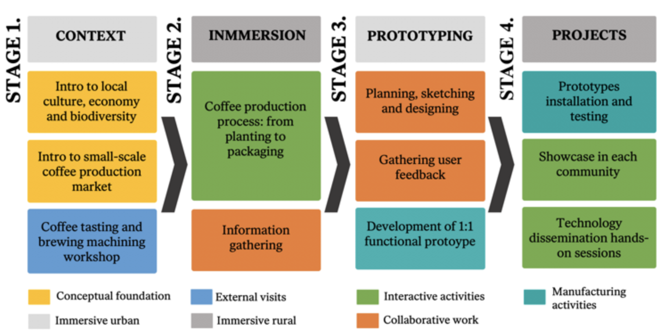
Stage 1. Focused on contextualizing students with the process of small-scale coffee production, in reference to each coffee-growing collective. This included in-person sessions with experts and other participants in the small-scale coffee production chain, as well as facilitated sessions with key institutions such as the National Coffee Federation of Colombia. Each partnering collective also provided in-depth background on local needs and opportunities.

Stage 2. The goal was two-pronged. First, to provide students with an immersive experience within each partnering. Second, to allow students to gather crucial information about projects by being in the field. Activities in this stage ranged from procuring, preparing and planting seedlings, to packaging for sale and distribution. For the majority of this stage, community members acted as course instructors.

Stage 3. This stage was focused on several iterations of planning, designing, and gathering feedback, all of them orchestrated in collaboration with partnering collectives. Each team was required to produce functional 1:1 prototypes. These were manufactured by teams at a local university.

Stage 4. The last stage of the process focused on installation and testing of prototypes. These were presented to each collective to its larger community in an open-door local showcase. These gatherings featured hands-on sessions teaching community members and farmers from neighboring villages how to replicate the prototypes produced.

Table I
CURRICULUM OVERVIEW



4) Results: Details about APRENAT and De Finca prototypes can be found on Table I and II respectively. Although the course also included prototypes in business and social dimensions, they are not reported in this paper.

The APRENAT group focused on conservation of bees that pollinate crop plantations, in return, providing benefits to the quality of coffee. Prototypes included a sensorized beehive, a manual honey press, and mobile point-of-sale furniture. The De Finca group worked on integrating an automated cooling system to an existing low-cost, locally manufactured coffee roaster. The system included power conditioning for the room where the roaster was installed, and the provision of protective gear.

Table II
APRENAT RESULTS

Product	Description
Technology	
Bee-hives	Guadua and wood board beehive low-cost, easy to manufacture designs.
Sensor system	Solar-powered, Arduino-based sensor system to measure hives' temperature and humidity, providing bees' health indicators.
Honey extraction press	Manual, rotating honey press to separate the honey and obtain by-products.

Table III
DEFINCA RESULTS

Product	Description
Technology	
Conditioning of coffee roasting room	Revamping of roasting room to comply with national standards.
Cooling and extraction system for coffee roaster.	DC motor coupled with shaft allowing uniform movement of coffee as it exits the roaster. Incorporates air cooling system and heat extraction.

IV. CONCLUSION

Based on our experience implementing this course, we highlight what we consider to be three key principles in facilitating this type of learning experience and discuss some of its challenges: 1) engaging in full community immersion; 2) positioning coffee farmers as learning instructors; 3) thick contextualization of the engineering design process.

A. Community immersion

By facilitating field-based design engineering, key contextual aspects to the engineering process of developing a technology are made available to students. For example, practicing activities related to the problem at hand along with local community members, can change the learning paradigm, providing students with a situated view from the user's perspective. This optic can be enriched with information about social, organizational, cultural and environmental values, all key elements to engineering and design, but rather difficult to imbue into a classroom-based experience.

Through immersion, experience becomes the compass for projects, there are no pre-established results. In the APRENAT project for example, this flexibility allowed the team to discover the virtuous cycle between beekeeping and coffee-growing, and pivot the project in that direction. This type of shift can be difficult to recreate in a classroom setting. Immersion allows for bonds of trust and communication to be strengthened, both of which are fundamental for long-term sustainability of projects. It is to be said that managing all these moving pieces can be cumbersome. For example, ensuring availability from community members, making sure sessions are effective, providing safe environments in a remote location, and managing transportation needs requires significant effort.

B. Community members as facilitators

Coffee is a craft: expertise is passed from generation to generation. Through this course, we are learning that including students as part of this cycle can yield valuable lessons for engineering education. Through a feedback survey following the end of the program, students reported gaining greater appreciation for non-traditional forms of knowledge as a result of learning directly from farmers. This shifting in power dynamics, where members of a traditionally marginalized group now occupy a position of privilege, could make it easier for students to externalize their own knowledge gaps and strengths. However, we acknowledge there is room to build on this power redistribution and explore mechanisms to better equalize benefits across all stakeholders. Our future work will focus on expanding these reflections.

C. Thick contextualization of design engineering processes

Course outcomes were tightly adapted to local conditions. Prototypes used only products and tools of easy local access. They were made in close partnership with community members, allowing for future production and dissemination as well as local repair and improvement. Their performance was optimized based on local conditions; for example, by adapting features and parameters of a coffee dryer based on local humidity and temperature.

Thick contextualization allows for gaps in knowledge to be identified and bridged on site. An engineer who intervenes and participates in the co-creation of any device, is capable of quickly identifying which specific knowledge must be transferred locally, for example, to improve the use and maintenance of a given technology.

Community work requires specific times, context helps highlighting local needs and limitations given that resources at disposal are scarce and expensive. This represents a direct call to creativity embodied by the need to solve problems with what the environment offers

V. Acknowledgements

The authors would like to thank the families of the APRENAT and DeFinca collectives for allowing their communities to become scenarios of transformation and learning. We thank the students who participated in the course for leaving their mark on the territory and enjoying a life experience. We thank the team of facilitators and the Center for the Innovation of Appropriate Technologies and Education, C-Innova, for their support in the design of the curriculum and their work on building a Latin American co-creation ecosystem.

References

[1] M. C. Ramírez, J. Plazas, C. Torres, J. C. Silva, L. C. Caicedo, and M. A. González, "A Systemic Framework to Develop Sustainable Engineering Solutions in Rural Communities in Colombia: Case Study: Ingenieros sin Fronteras Colombia," Syst Pract Action Res, vol. 25, no. 2, pp. 95–116, Apr. 2012, doi: 10.1007/s11213-011-9203-y.

[2] J. Goggins, "Engineering in communities: learning by doing", Campus-Wide Info Systems, vol. 29, no. 4, pp. 238–250, Aug. 2012, doi: 10.1108/10650741211253831.

[3] I. de los Ríos, A. Cazorla, J. M. Díaz-Puente, and J. L. Yague, "Project–based learning in engineering higher education: two decades of teaching competences in real environments," Procedia - Social and Behavioral Sciences, vol. 2, no. 2, pp. 1368–1378, 2010, doi:10.1016/j.sbspro.2010.03.202.

[4] J. Schneider, J. A. Leydens, and J. Lucena, "Where is 'Community'?:Engineering education and sustainable community development," European Journal of Engineering Education, vol. 33, no. 3, pp. 307–319, Jun. 2008, doi: 10.1080/03043790802088640.

[5] B. Amadei, R. Sandekian, and E. Thomas, "A Model for Sustainable Humanitarian Engineering Projects," Sustainability, vol. 1, no. 4, pp. 1087–1105, Dec. 2009, doi: 10.3390/su1041087.

[6] J. A. Leydens and J. C. Lucena, "Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service," International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, vol. 9, no. 2, pp. 1–28, Sep. 2014, doi: 10.24908/ijsle.v9i2.5447.

[7] A. W. Astin, L. J. Vogelgesang, E. K. Ikeda, and J. A. Yee, "How Service Learning Affects Students," p. 7, 2000.

[8] A. R. Bielefeldt, K. G. Paterson, and C. W. Swan, "Measuring the Value Added from Service Learning in Project-Based Engineering Education,", International Journal of Engineering Education, p. 535-546, 2010.

[9] B. Ropers-huilman, L. Carwile, and M. Lima, "Service-learning in engineering: a valuable pedagogy for meeting learning objectives," European Journal of Engineering Education, vol. 30, no. 2, pp. 155–165, May 2005, doi: 10.1080/03043790410001664363.

[10] J. D. J. Vandersteen, C. Baillie, and K. Hall, "International humanitarian engineering," IEEE Technol. Soc. Mag., vol. 28, no. 4, pp. 32–41, 2009, doi: 10.1109/MTS.2009.934998.

[11] C. Skokan, M. Simoes, J. Crocker, and U. Building, "Designing Humanitarian Engineering Classes," presented at the 9 th International Conference on Engineering Education, 2006.

[12] E. J. Coyle, H. G. Dietz, and L. H. Jamieson, "Long Term Community Service Projects In The Purdue Engineering Curriculum," 1996.

[13] W. C. Oakes, E. J. Coyle, and L. H. Jamieson, "EPICS: A Model Of Service Learning In An Engineering Curriculum," 2000.

[14] M. K. Ravel, B. Linder, W. C. Oakes, and C. B. Zoltowski, "Evolving engineering education for social innovation and humanitarian impact—Lessons learned across a range of models," in 2015 IEEE Global Humanitarian Technology Conference (GHTC), , pp. 169–176, Oct. 2015, doi: 10.1109/GHTC.2015.7343969.

[15] E. B.-N.Sanders, "From user-centered to participatory design approaches," in Design and the Social Sciences, vol. 20020425, J. Frascara, Ed. CRC Press, 2002, pp. 1–8.

[16] N. L. Atkinson, S. L. Saperstein, S. M. Desmond, R. S. Gold, A. S. Billing, and J. Tian, "Rural eHealth Nutrition Education for Limited-Income Families: An Iterative and User-Centered Design Approach," Journal of Medical Internet Research, vol. 11, no. 2, p. e21, 2009, doi:10.2196/jmir.1148.

[17] M. Kam, D. Ramachandran, A. Raghavan, J. Chiu, U. Sahni, and J. Canny, "Practical considerations for participatory design with rural school children in underdeveloped regions: early reflections from the field," in Proceedings of the 2006 conference on Interaction design and children, Tampere, Finland, Jun. 2006, pp. 25–32, doi: 10.1145/1139073.1139085.

[18] MIT D-Lab." https://d-lab.mit.edu/ (accessed Apr. 10, 2020).

[19] B. J. Ranger and A. Mantzavinou, "Design thinking in development engineering education: A case study on creating prosthetic and assistive technologies for the developing world," Development Engineering, vol. 3, pp. 166–174, Jan. 2018, doi: 10.1016/j.deveng.2018.06.001.

[20] E. H. J. Morrison, A. Banzaert, C. Upton, N. Pacini, J. Pokorný, and D. M. Harper, "Biomass briquettes: a novel incentive for managing papyrus wetlands sustainably?," Wetlands Ecol Manage, vol. 22, no. 2, pp. 129–141, Apr. 2014, doi: 10.1007/s11273-013-9310-x.
[21] "Affordable Design & Entrepreneurship (ADE)," Olin College of Engineering – Admissions Microsite, Jun. 21, 2017. http://meet.olin.edu/olin-isms/affordable-design-entrepreneurship-ade (accessed Apr. 10, 2020).
[22] Noyes, Erik; Linder, Benjamin., "Developing undergraduate entrepreneurial capacity for social venture creation," ProQuest. https://search.proquest.com/openview/7b4a0a840c65369b18cf38173cc 253e4/1?pq-origsite=gscholarcbl=28224 (accessed Apr. 10, 2020).
[23] "Design for Extreme Affordability." https://extreme.stanford.edu/ (accessed Apr. 10, 2020).
[24] "The State of Agricultural Commodity Markets 2018 — FAO." http://www.fao.org/family-farming/detail/en/c/1153339/ (accessed Apr. 10, 2020).
[25] F. Ssozi-Mugarura, E. Blake, and U. Rivett, "Supporting community needs for rural water management through community-based codesign," in Proceedings of the 14th Participatory Design Conference: Full papers - Volume 1, pp. 91–100, Aarhus, Denmark, Aug. 2016, doi: 10.1145/2940299.2940311.
[26] A. Capaccioli, G. Poderi, M. Bettega, and V. D'Andrea, "Participatory infrastructuring of community energy," in Proceedings of the 14th Participatory Design Conference: Short Papers, Interactive Exhibitions, Workshops - Volume 2, pp. 9–12, Aarhus, Denmark, Aug. 2016, doi: 10.1145/2948076.2948089.
[27] P. Siozos, G. Palaigeorgiou, G. Triantafyllakos, and T. Despotakis, "Computer based testing using 'digital ink': Participatory design of a Tablet PC based assessment application for secondary education," Computers & Education, vol. 52, no. 4, pp. 811–819, May 2009, doi: 10.1016/j.compedu.2008.12.006.
[28] "IDDS 2007 at MIT — International Development Innovation Network."http://www.idin.org/blog-news-events/events/idds-2007-mit (accessed Apr. 10, 2020).
[29] P. Reynolds-Cuéllar and D. Delgado Ramos, "Community-Based Technology Co-Design: Insights on Participation, and the Value of the "Co"", In Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 1 (PDC '20). Association for Computing Machinery, New York, NY, USA, 75–84. DOI:https://doi.org/10.1145/3385010.3385030.
[30] H. P. Molano et al., "Design for Reconciliation: Co-designing a Peaceful Future in Post-conflict Zones in Colombia," Diseña, no. 13, pp. 140–173, Sep. 2018, doi: 10.7764/disena.13.140-173.
[31] S. Buitrago Guzmán and P. Reynolds-Cuéllar, "Achieving grassroots innovation through multi-lateral collaborations: evidence from the field", In Journal of Peer Production, Vol. 12, 2018/7.
[32] J. Hartley and J. Benington, "Co-research: A new methodology for new times," European Journal of Work and Organizational Psychology, Sep. 2010, doi: 10.1080/13594320050203085.
[33] K. Maclean, "Crossing cultural boundaries: Integrating Indigenous water knowledge into water governance through co-research in the Queensland Wet Tropics, Australia," Geoforum, vol. 59, pp. 142–152, Feb. 2015, doi: 10.1016/j.geoforum.2014.12.008.
[34] A. Dearden, A. Light, T. Zamenopoulos, P. Graham, E. Plouviez, and S. de Sousa, "Scaling up co-design: research projects as design things," in Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts - Volume 2, Windhoek, Namibia, Oct. 2014, pp. 67–70, doi: 10.1145/2662155.2662182.
[35] K. Maclean and L. Cullen, "Research methodologies for the coproduction of knowledge for environmental management in Australia," Journal of the Royal Society of New Zealand, vol. 39, no. 4, pp. 205–208, Dec. 2009, doi: 10.1080/03014220909510581.
[36] R. G. Paulston, Social Cartography: Mapping Ways of Seeing Social and Educational Change. Garland Reference Library of Social Science, Volume 1024; Reference Books in International Education, Volume 36. Taylor Francis, 47 Runway Rd, 1996.
[37] "De Finca," DE FINCA. https://defincacolombia.weebly.com/ (accessed Apr. 10, 2020).
[38] "APRENAT," Aprenat. https://aprenat.org/ (accessed Apr. 10, 2020).
[39] K.A. Taha, "Creative capacity building in post-conflict Uganda. Dissertation, Massachusetts Institute of Technology, 2011.