GENDER ATTITUDES AND IDENTITIES IN KENYA'S TECH SECTOR

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ABSTRACT

Kenya's technology sector is one of the largest national tech sectors on the African continent and the premier tech sector in eastern Africa. As such, there is significant interest in those who work in Kenya's tech sector, especially with regard to the sector's reputation as being dominated by men. In eastern Africa, understanding the historical construction of either *ethnicity* or *gender* requires treating them as intertwined and overlapping, such that no single identity can be completely understood without its relation to the other. Far from essentialized categories of behavior and practices among distinct groups of people, *gender* and *ethnicity* represent meaningful identities individuals hold that have been made and remade through social and cultural processes over time. Prior to colonization, most communities adhered to and reinforced a gendered division of labor, which British authorities then exploited in their colonial conquests to justify dividing communities into distinct *tribes* (*ethnicities*) to facilitate their "indirect rule" over the region. At the endpoint of British occupation in December of 1963, there remained a significant gender disparity in Kenya with respect to ownership, agency, and economic activities available to men compared to women. During the post-colonization period, from 1964 to today, Kenyan conceptualizations regarding gender norms have in many ways remained stubbornly resistant to change, though in recent years have seen some movement. Within the context of Kenya's technology sector, the concept of gender and its shifting conceptualizations are impacted by tech development projects of governmental and nongovernmental international development projects, for-profit technology innovation initiatives, and online collectives of Kenyan women.

In this dissertation I seek to contribute meaningfully to our understanding of identities held by members of Kenya's tech sector, their impact on the gender disparity in the sector how

gender norms and attitudes may be shifting in recent years, and draw from the manuscripts presented here the methodological lesson about the building of *communities of practice*.

I further argue for the importance of *intersectionality* and its applications to future research. I discuss how broadening gender-based research in the tech sector to include an intersectional approach to individuals' identities will produce a deeper understanding of how different aspects of one's identity affect that individual's attitudes and beliefs about gender norms. Crucial to intersectional feminism is in seriously pursuing all facets of oppression, rather than paying some attention to non-gendered oppressions only when doing so serves to benefit partial progress in reducing oppression of women. Ultimately, this dissertation seeks to argue for incorporating intersectionality into the design, data collection methods, and analyses of research projects undertaken within the sector, in service of an intersectional feminist approach to development of the sector.

To my Grandma Vi, who through her life demonstrated to me the importance of persistence, particularly in the face of seemingly-insurmountable obstacles, and who ensured I learned from an early age a strong ethical and moral code that insists upon caring first for those who society treats as last.

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INTRODUCTION

Kenya's technology sector is one of the largest national tech sectors on the African continent and the premier tech sector in eastern Africa. The government of Kenya's mid-term development plan, announced as Vision 2030 by former president Mwai Kibaki in 2008, privileges the tech sector as a key component of its financial future (Government of Kenya 2008). The plan includes a literal tech-centric metropolis called "Silicon Savannah," which is wrapping up the first phase of construction, as the government has just announced more than $1.2 billion USD investment by more than 140 national and international investors and has opened parts of the city for residential and commercial occupation (Mungadze 2025; Mwende 2024).

As such, there is significant interest in those who work in Kenya's tech sector, especially with regard to the sector's reputation as being dominated by men; the gender disparity in the sector has not gone unnoticed (Domingo 2023; Rotich 2025). In this dissertation I seek to contribute meaningfully to our understanding of identities held by members of Kenya's tech sector, their impact on the gender disparity in the sector how gender norms and attitudes may be shifting in recent years, and draw from the manuscripts presented here the methodological lesson about the building of *communities of practice*.

I further argue for the importance of *intersectionality* and its applications to future research. I discuss how broadening gender-based research in the tech sector to include an intersectional approach to individuals' identities will produce a deeper understanding of how different aspects of one's identity affect that individual's attitudes and beliefs about gender norms. Crucial to intersectional feminism is in seriously pursuing all facets of oppression, rather than paying some attention to non-gendered oppressions only when doing so serves to benefit

partial progress in reducing oppression of women. Ultimately, this dissertation seeks to argue for incorporating intersectionality into the design, data collection methods, and analyses of research projects undertaken within the sector, in service of an intersectional feminist approach to development of the sector.

In this introductory chapter I begin by covering literature about the concepts of *gender* and *tribe/ethnicity* as they relate to Kenyan communities, before moving to the *community of practice* theoretical framework that I use in the manuscripts following this chapter. Next, I provide a brief introduction to how international development projects have engaged with Kenya's technology sector. I follow this with summarizations of each of the three manuscripts included in this dissertation, before overviewing my conclusion.

Gender and *Ethnicity* in Eastern Africa

Gender and *ethnicity* as identities have a deep and complicated history in eastern Africa, which will require an intersectional treatment in my study alongside other identities such as religion or class. In eastern Africa, understanding the historical construction of either *ethnicity* or *gender* requires treating them as intertwined and overlapping, such that no single identity can be completely understood without its relation to the other (Hill Collins and Bilge 2016). Contemporary conceptualizations of *ethnicity* and *gender* in the region are no different. This intersection is perhaps best illustrated through an exploration of their deep roots within the historical period of the region's colonization by European, especially British, authorities. Far from essentialized categories of behavior and practices among distinct groups of people, these categories represent meaningful identities individuals hold that have been made and remade through social and cultural processes over time. Anthropological scholarship about eastern

Africa and utilizing *ethnicity* and *gender* since the latter half of the 20th century has generally critically interrogated these concepts through a constructivist lens.

Mafeje argues that the concept *tribe* – and in many cases, tribes themselves – was invented by especially British colonizers and anthropologists, who were prolific in their use of it early on (Mafeje 1971:254). Anthropologists set out to describe static groups of people, delineated by geographic boundaries, and in many cases those scholars ignored or underreported significant events of cultural change (Mafeje 1971). Colonial authorities then relied on anthropological descriptions that conflated African groups with political communities, which they could then rule under their colonial regime. Authorities utilized these political categorizations to carve up African peoples in their colonial territories and justify installation of hand-picked elites into politically administrative leadership roles, who then reported to colonizers, in a system of "indirect rule" (qtd. Mafeje 1971, 254; see also Iliffe 1979; Ambler 1988; Lonsdale 1994; Hodgson 2001) . This social construction is important in recognizing how *tribe* as it was conceptually used during colonization, is a direct equation to *ethnicity*; Kenyans still use the term *tribe* when identifying *ethnicities* and hold that *tribes* are blood-derived affiliations which individuals cannot change (Hornsby 2012, 21; Lynch 2006).

With respect to *gender*, Kitching (1980) and Lonsdale (1992a) include investigation of apparently dramatic changes in a given group's gendered labor and behavior divisions. Prior to colonization, most communities adhered to and reinforced a gendered division of labor (G. Kitching 1980; Hodgson 2005). McClintock (1995) explains how the centrality of *woman* manifests explicitly in a gendered inequality present prior to colonization, which British authorities then exploited in their colonial conquests. Colonizers shifted the specifics of gender norms, customs, and behaviors as a part of their codification of *tribal* customs, which

represented dramatic changes in a given group's gendered labor and behavior divisions and markedly grew the imbalance between men and women in every community that found itself under their rule (G. Kitching 1980; Lonsdale 1992c; Hodgson 2001). Conceptual divisions between genders were almost-certainly not invented or established by British authorities upon colonization of eastern Africa or during colonial occupation, but did serve as important differences in practices and behavior that helped authorities justify their *tribal* categorizations.

The critical interrogations of how *tribe* (or *ethnicity*) and *gender* were constructed or altered during colonization may be best encapsulated through the concept of *tradition*, especially as presented in Ranger (1983) and critiqued in Ranger (1999). In the former, Ranger presents the argument that *tradition* was a specifically European conceptual invention, which colonial authorities imported to their colonized lands as a tool with which to organize and render intelligible the communities they were controlling and exploiting:

> Since so few connections could be made between British and African political, social and legal systems, British administrators set about inventing African traditions for Africans. Their own respect for 'tradition' disposed them to look with favour upon what they took to be traditional in Africa. They set about to codify and promulgate these traditions, thereby transforming flexible custom into hard prescription. (Ranger 1983, 212)

For Ranger, *tradition* is the particular collection of behaviors and practices of a particular group (including their particular language and dialect as well as their gendered behavioral divisions), which serves as a framework with which to set apart one group from others. Authorities brought this framework with them to their colonies in order to conceptually organize those they were tasked with ruling. This argument however runs the risk of being too constructivist in its treatment of African ethnic identity, as it might lead to the conclusion that African *ethnic* identities are entirely owed to British colonizers.

Ranger responds to this in the latter of the aforementioned pieces to clarify his argument:

> [E]thnic identity *was* a pre-colonial possibility. This took two forms: fully developed ethnicity and what might be called latent ethnicity… Ethnicity, it seems to me, is not a given primordial identity but an ideologically asserted one. It depends on the ideological assertion of the centrality of language, and of the superiority of one language, or dialect, to another. This does not merely mean insistence on a language of state… It means insistence on a language as a criterion of membership of the collectivity and on dialect as a citerion of hierarchies and prestige… Ethnicity also depends on the ideological assertion that not only the ruling lineage but also the people are linked by 'blood'. (Ranger 1999, 139–40 emphasis in original)

Ranger's clarification makes it clear: it was never his intent to deny Africans the ownership of their own *ethnic* identities, but rather to question the meaning behind some of those identities' coalescence, which conspicuously coincided with colonial rule. According to Ranger, it isn't so much that *ethnic* identities were created from nothing by colonizers, but rather that colonizers acted upon existing practices and behaviors – which few communities viewed as meaningfully identifying and thus worthy of building their own collective identity upon – as a means of organizing those communities they were expected to rule.

Community of Practice as a Theoretical Framework

Community of practice is a theoretical framework for investigating groups of individuals who have common goals and interests, where their pursuits of those bring them together in either formal or informal settings. Originally proposed in Lave and Wenger (1991), *community of practice* serves to account for members of a community who seem to be engaging in the same kinds of practices and behaviors as the rest, but who may not be participating at a level that would match the intensity or frequency of other, established community members. Alternatively, Duguid (2005) describe a network of practice as differing from a community of practice by its flipped emphasis: in a network of practice, practitioners are bound through "learning about" a subject, rather than "learning to be" members of a community (Duguid 2005, 113).

Though the explanatory example in Lave and Wenger (1991) focuses upon not-yet-trained apprentices engaged with their instructors in any number of activities, which may seem to limit this theoretical framework to cases of knowledge transmission and adoption, Duguid (2005) emphasizes the social behaviors inherent in the learning process itself. For Duguid, the binding social activity isn't the process of "learning about" any particular subject that a community may or may not concern itself with, but rather "learning to be" someone in that community, and thus "knowing how" the community practices (2005, 113).

International Development and Kenya's Technology Sector

International development literature frequently discusses the importance of women's empowerment as a means of lifting a population overall, especially within the most economically-productive sectors of a country's economy (Kabeer 1999; United Nations 2015). Kenya's technology sector is frequently described as crucial to the country's economic future; for instance, the World Bank describes current economic projections of the sector's growth as being at a year-over-year rate at 10.7% as recently as 2017 (World Bank Group 2017). Over the past decade, Western world venture capitalist interest Kenya's tech sector increased significantly, spurred by two major industry successes: M-PESA, a cell phone money transfer system started in 2007 by Safaricom (Eijkman, Kendall, and Mas 2010; Marchant 2015); and Ushahidi, a cell phone application for reporting politically motivated violence, which launched in early 2008 in the wake of Kenya's contested 2007 election (Kobia 2010; Marchant 2015). Noting these successes, in 2008 President Kibaki announced a part of the Vision 2030 development plan to include building up the small community of Konza in Machakos County into a literal "Silicon Savannah," a tech-centric metropolis named using the sector's unofficial moniker based upon the

Silicon Valley in the United States. The sector's importance situates its professionals favorably as people with considerable political, economic, and social power within and outside the country.

Eleanor Marchant has described through her ethnographic writing how the success of Ushahidi has perhaps had the most impact on the reputation of Kenya's tech sector (2015; 2017). Erik Hersman, one of Ushahidi's founders and creators, went on to co-establish iHub, a world renowned tech innovation center in Nairobi – "described as the first tech hub in Africa" – where tech entrepreneurs meet to collaborate and assist each other with technical issues (Marchant 2017:314). In fact, the overwhelming success of both Ushahidi and iHub have for the foreseeable future tied Kenya's tech sector directly to the realm of international development (Marchant 2015). For instance, IBM operates a tech research facility in Nairobi, which describes itself as being concerned with technological solutions to characteristically development-oriented issues such as those in education, sanitation, or transportation (Marchant 2015).

"Teaching with Avida-ED": The *Community of Practice* Theoretical Framework and Methods for Data Collection

The first manuscript ("Teaching with Avida-ED: instructor experiences following an in-person professional development program aimed at increasing active learning and experimentation in evolution education" Geyer, Smith, and Pennock 2024) is a study of the experiences of educational professionals who attended one of eight multi-day Active LENS workshops, where they learned about the Avida-ED computer program and how to effectively incorporate it into a biology course curriculum for teaching about evolutionary theory. Importantly, attendees were not merely learning about Avida-ED as an abstract teaching tool; their invitation to a workshop came with expenses paid, but also stipulated the expectation that they would use Avida-ED in an educational setting at least once following their attendance; by attending they were learning to be Avida-ED instructors.

Workshops were held over five years, at multiple universities, with attendees from diverse pedagogical backgrounds – including high school science teachers, college preparation course instructors, college biology faculty, and even college computer science faculty – and with workshop content varying slightly from year to year. Multiple attendees, including one who participated in the study, attended virtually. Despite the diversity in employment; instruction level; and time, location, and mode of attendance this study considered anyone who attended one of the workshops as a part of the pool for soliciting participation in a study interview and treated responses from all participants as being from individuals within a cohesive unit. Implicit to this approach was that the pool of attendees, and thus the final cohort of participants, was a *community of practice*.

As my co-authors and the rest of their research team were less familiar with qualitative research study design, implementation, and data analysis, I was brought to provide expertise in these areas. This study was designed in the early days of the global COVID-19 pandemic, while nearly all educators were working from home and providing instruction via videoconferencing. We took care to plan the expected timeline of each interview, including my co-interviewer's greetings to the participant and my introduction to them. What is not discussed in the article is that we also deliberately standardized our personal interview environments to maintain consistency, limit distractions, and maintain professional backgrounds, without using the videoconferencing software's background blurring feature. The study relied on a prepared semi-structured interview protocol, which was iterated upon once and reevaluated (but left alone) a second time. This article's appendices (included in this dissertation because they are referenced in the article) are also available for download via the original online publication as supplementary files, which include as Appendix B the final form of our semi-structured

interview protocol, and as Appendix C a sample coding instrument for data compilation and analysis.

Identity and Students in Kenya's Tech Sector

The second manuscript in this dissertation ("Educational Training Opportunities in Kenya's Technology Sector: Qualitative Data Collection Report") was submitted to the World Bank's Gender Innovation Lab (GIL) following a preliminary qualitative study investigating women's participation in learning opportunities at a for-profit tech education company in Nairobi, Kenya. This report described demographic details about those who had participated via interviews or focus groups, conducted by a Kenyan research assistant and myself.

The report also includes three appendices: an in-depth interview protocol, an in-depth focus group protocol, and consent scripts for use in either an interview or focus group setting. I developed the protocols in consultation with GIL social scientists; both protocols included in this report are in their final form. The interview protocol reflects three iterations of adjustments, following the early interviews the research assistant and I conducted. At the sociologists' initial requests, this protocol includes a lot of detail and specified order of conversation topics. As such, it is more characteristic of a structured protocol than a semi-structured one. However, following my recommendation, we used a semi-structured protocol for the focus groups, which were held later into the data collection process because we relied on interview participants to recommend friends or colleagues for inclusion in the focus groups. Because it was written much later into the data collection process, it did not require iterative updates. The final appendix is the consent language I drafted for use for all participants. This language has become the starting point I use for similar qualitative research.

The report itself details the demographics of study participants, but because it is an internal data-only report, it does not contain discussion of literatures relevant to the implications of the study results. When I was originally hired for this project, the GIL social scientists were planning the study to only consider age and gender when analyzing participant responses. During preliminary discussions I advocated for a broader collection of identities to be considered, should they prove meaningful during analysis. We ultimately agreed to collect information about participants' age, gender, ethnicity, and religious beliefs. To provide some contextual insight to the study design once I was brought to the project, I have included a short forward presenting some theoretical perspectives about intersectionality and feminist research, which represent my perspective during conversations with GIL social scientists at the outset of the study.

Gender Norms in Kenya's Tech Sector

The final manuscript ("Gender Norms and Attitudes among Kenya's Tech Sector Professionals") covers attitudes and beliefs about gender norms in Kenya, as shared with me by tech sector employees and students. This article relies on participant observation and interview data I collected in Nairobi and Kisumu, two cities in Kenya, in 2021 and 2022, as well as general observations I have made during several stays there from as far back as 2010. I joined two separate tech communities – an introductory web programming course offered by a technology innovation center in Kisumu called LakeHub, and a technology research team as part of a technology research center at Strathmore University in Nairobi – to engage in participant observation for several months, before soliciting community members for interviews about their experiences related to gender within the tech sector. This study seeks to investigate current gender norms in Kenyan society and provide insight into how norms might be changing in recent years.

To contextualize *gender* as it relates to Kenyan society, I provide a brief overview of literature relevant to the concept's connection to British colonization of the region, with specific attention to specific examples of changes brought about by Britain's colonial project. I also overview how Kenya's tech sector quickly grew in prominence, including the successes widely-recognized as having brought attention to the sector in 2007 and 2008 and the drastic increases in data throughput that the country has seen via fiber optic cables that connect the country to the rest of the world's digital networks. I discuss how tech communities actively impact gender norms in the country, using an online-first movement from 2014 called #MyDressMyChoice, which began in response to a widely-publicized, terrible act of gender-based violence in Nairobi.

The data I discuss in this article show glimpses of already-shifted gender norms, attitudes held by tech sector men and women indicating their own criticisms of known gender stereotypes about especially women in the sector, and anxieties about members of Kenya's LGBTQ community and their perceived impact upon society. I discuss potential avenues for future research, including ideas for incorporating a mixed methods approach to data collection about identity, which would enrich future studies with deeper understanding in how different identities may impact beliefs held by those in the sector.

Conclusion

The final chapter of this dissertation begins with a restatement of its three purposes: to provide insight into how identities have an impact on Kenyans working in the country's tech sector; to contribute to academic literature about how *intersectionality* can be employed when designing qualitative research about Kenya's tech sector, as well as during the data collection and data analysis phases of that research; and to describe the methodological lesson which arises

from the three manuscripts contained herein, which is that *communities of practice* can be constructed and shaped by practitioners, whether consciously or not.

I first begin by explaining how COVID-19 impacted the originally-planned trajectory of this dissertation, how the pandemic was the direct cause of my involvement in the study that resulted in Manuscript One, and how the changes to my proposed data collection phase resulted in the basis for Manuscript Three. I then turn to the concept of *intersectionality*, to discuss more-specific COVID-19 impacts to my data collection which hampered my ability to incorporate the concept meaningfully into the study I ultimately undertook. I explain the incorporation of Manuscript Two into this dissertation, to reincorporate *intersectionality* as an important analytical concept for research into Kenya's tech sector and build an argument for how such research can aid intersectional feminist research and activism, particularly when researchers take seriously the call by intersectional feminist theorists to tackle oppressions of all kinds by decentering *woman* as the primary focus. I argue that this is not to push women aside, but rather to ensure that any work done to eliminate inequities for women does not become short-lived because inequities for others are allowed to thrive, which would allow those inequities to creep back onto woman at a later date.

Finally, I discuss the methodological lesson to be drawn from the manuscripts in this dissertation, that *communities of practice* can be constructed by their practitioners, whether constructed consciously or not. I discuss how scholars have framed *communities of practice* via theoretical means, particularly among scholars writing about development contexts and the communities being framed are shown to contain practitioners who are actively engaged with one another. To extend this, I discuss how the *communities of practice* within Manuscripts One and Three are actively constructed by the practitioners themselves: unintentionally, but wholly from

the ground up, in the case of Manuscript One; and consciously in Manuscript Three, but through attempts to shape the community rather than outright build it. I end the chapter by noting the importance of both this methodological lesson and an intersectional feminist approach to study design, data collection, and data analysis, will improve future research into Kenya's tech sector.

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MANUSCRIPT ONE: TEACHING WITH AVIDA-ED: INSTRUCTOR EXPERIENCES FOLLOWING AN IN-PERSON PROFESSIONAL DEVELOPMENT PROGRAM AIMED AT INCREASING ACTIVE LEARNING AND EXPERIMENTATION IN EVOLUTION EDUCATION

Forward

This article was first published as [Geyer, Brian Samuel, James J. Smith, and Robert T. Pennock. 2024. "Teaching with Avida-ED: Instructor Experiences Following an in-Person Professional Development Program Aimed at Increasing Active Learning and Experimentation in Evolution Education." Evolution: Education and Outreach 17 (17)]. It is reprinted here with permissions from Drs. Pennock and Smith, as well as with permission from Springer Nature. The original can be found at https://doi.org/10.1186/s12052-024-00211-2. Appendices A and C to this chapter have been significantly altered due to content decisions made by the department responsible for reviewing dissertation formatting at Michigan State University. To view the correct version of these appendices, please find them online as supplementary files to the publication.

Abstract

Avida-ED is a model system that lets students explore evolution and the nature of science by observing and manipulating the evolutionary dynamics of digital organisms. Over five years, we ran eight 2.5-day in-person professional development workshops for 105 primarily college biology instructors to introduce them to Avida-ED and digital evolution and to help them to plan implementations. In this paper, based upon 60-minute interviews with 46 of the attendees, we describe what they found to be of value in the workshop itself and the implementations of Avida-ED that they subsequently carried out. The Active LENS workshops were universally valued by the interviewees as a professional development experience; they valued the overall experience of the workshops, their organization and content, and the instructor support materials.

Of the 46 teachers that we interviewed, 41 implemented Avida-ED in their classrooms, in 66 separate implementations. We characterized these with respect to the nature of the implementation and its duration, and examined the data in relation to course type, course level, and stated learning goals of the instructors. The most common use was to have students learn evolutionary concepts by observing them in action. A smaller fraction used it to provide a complete research experience.

Introduction

Despite its central place as the foundational concept in biology (Dobzhansky 1973), as well as being integral to reform biology teaching recommendations (AAAS 2011; NRC 2012b; Brownell et al. 2014), the effective teaching of evolution remains one of the major challenges in undergraduate biology education. The reasons for this are many and varied. Understanding of evolution requires overcoming the naive intuitive reasoning about biological phenomena common in many students (Gregory 2009) and the synthesis of abstract biological concepts across temporal and spatial scales (White et al. 2013), which sometimes involves mastering "threshold concepts" (Tibell and Harms 2017) and avoiding misunderstandings about emergent phenomena (Cooper 2017). In addition, there are well-characterized societal pressures to reject fundamental evolution concepts (Scott 2005). Nelson (2008) argued that many instructors teach evolution concepts ineffectively; he suggested that using interactive engagement, critical comparisons of evidence, and directly addressing common misconceptions is essential for promoting student learning. Active and inquiry-based pedagogies are some of the best-known evidence-based reformed teaching practices, and many published biology education research studies have shown not only the efficacy of active learning (compared to traditional) approaches, but also have shown that reformed pedagogies tend to promote the success and retention of

people in traditionally underrepresented groups (Nelson 2008; Armbruster et al. 2009; Freeman et al. 2007; Freeman et al. 2014; Dirks 2011; Dewsbury et al. 2022). The research literature also makes clear the value of inquiry-based learning in helping students practice solving problems to increase their abilities to think critically and improve their quantitative literacy (NRC 2012a; Goldey et al. 2012; Wilkins 2016; Mentkowski et al. 2016). However, such active and inquiry-based learning is difficult to implement in evolution education because evolutionary processes involve slow changes in populations of organisms over hundreds and thousands of generations, which precludes the kind of hands-on experimentation one can conduct in lab classes in other sciences. The Active LENS project worked to address these challenges using the Avida-ED digital evolution platform.

Based on the Avida research platform used by researchers, Avida-ED is an artificial life model system that allows students to explore evolutionary concepts and carry out evolution experiments using digital organisms (Pennock 2007; Speth et al. 2009; Smith et al. 2016; Kohn et al. 2018). Free and readily available online (avida-ed.msu.edu), the program is supplemented by teacher support materials, including model exercises and published activities and instructional sequences (Johnson et al. 2011a; Johnson et al. 2011b; Lark et al. 2014; Smith et al. 2016; Kohn et al. 2018). Avida-ED allows students to engage evolution as an experimental science, rather than as a body of historical facts, providing them with opportunities to confront their misconceptions about evolutionary processes directly via active engagement and experimentation. It lets them wrestle with threshold concepts, such as randomness (Tibbell and Harms 2017) so they can overcome misconceptions through direct encounters with experimental evidence. These aspects of Avida-ED make it ideally suited for both inquiry-based lab experiences (Sundberg and Moncada 1994) and course-based undergraduate research

experiences (CUREs; Auchincloss et al. 2014), both of which allow students to engage in the complete set of scientific practices identified in the National Research Council's Next Generation Science Standards (NRC/NGSS; NRC 2012a).

To encourage and assist biology teachers who were interested in incorporating Avida-ED in their courses and equip them to train others themselves, we designed and produced a series of Active LENS professional development Training of Trainers (ToT) workshops. Faculty professional development programs are a common and effective way to introduce faculty to new pedagogical tools, such as Avida-ED, whose adoption and adaptation may require new technological knowledge and skills on the part of instructors (Gerard et al. 2011; Lark et al. 2020). In general, professional development programs that focus on subject matter, are of long duration, and incorporate social engagement among participants have been observed to be most effective (Garet et al. 2001; Wilson and Berme 1999). Further, Gerrish et al. (2015) noted that because biology faculty have different levels of understanding of evolution concepts, they have additional needs for professional development and curriculum support materials to gain the pedagogical content knowledge (PCK) necessary to implement new tools in the classroom related to evolution. In addition, computer programs such as Avida-ED require instructors to gain additional technological pedagogical content knowledge (Lark et al. 2020; Mishra and Koehler 2006) associated with the incorporation of a new technology in their classroom.

The 2.5-day Active LENS workshops were held at Michigan State University (MSU) in 2015 and 2016, MSU and the University of Washington in Seattle in 2017, MSU and North Carolina Agricultural and Technical University in 2018, and MSU and the University of Texas in Austin in 2019, which 105 individuals from across the United States attended over the course of

the five-year period (Table 1).[1] Each of these consisted of prepared talks and working sessions: the talks, given by the project PIs, introduced Avida-ED and provided background on its history, theoretical foundation, and programming as well as to experimental evolution in general and to pedagogical design for active learning for evolution; in the working sessions, attendees were introduced to Avida-ED as students on Day 1, and coached while preparing Avida-ED curriculum and lessons as instructors on Day 2. Attendees presented the results of their working

Table 1.1: Avida-ED Active LENS Workshop Cohorts.

Cohort	# Attendees[a]	# Study Participants	% Participated	# Known Implementers[b]	% Implemented[b]
2015 MSU	19	6	31.6%	13	68.4%
2016 MSU	16	9	56.2%	13	81.2%
2017 UW (Seattle, WA)	13	6	46.2%	6	46.2%
2017 MSU	11	8	72.7%	10	90.9%
2018 NCAT (Greensboro, NC)	12	2	16.7%	3	25.0%
2018 MSU	15	6	42.8%	7	46.7%
2019 UT (Austin, TX)	7	3	37.5%	5	71.4%
2019 MSU	12	6	46.2%	5	41.7%
Total	105	46	43.8%	62	59.0%

Notes:
a - # Attendees includes all who met the requirements outlined in "Study Participant Recruitment"
b - # Known Implementers includes individuals who implemented but did not participate in the study. We were made aware of these additional implementations by communications with the Attendees themselves and/or with Study Participants.

[1] Additionally, another 50 individuals attended a 1-day virtual workshop held in 2020 during the COVID-19 pandemic and over 200 attended half-day demonstration workshops we put on at various conferences. Because these workshops differed substantially from the full version, we omitted them from this study.

sessions on Day 3. A representative schedule for an Active LENS workshop is included as Supplementary File 1.

In this paper, we report and discuss the experiences of college teaching faculty (instructors) and high school teachers who attended these workshops. Forty-six workshop attendees (out of 105 attendees total) made themselves available to be interviewed in the latter half of 2020. Each 60-minute interview was held via video conference. We queried each instructor about the impact the Active LENS workshops had on their own teaching and professional development, the extent to which they had incorporated Avida-ED into their classrooms, and the learning outcomes workshop attendees hoped to achieve in their students when using Avida-ED. Although some instructors also discussed their perceptions of learning improvements among their students, this study did not collect data about student learning as a result of workshop attendance and Avida-ED classroom implementations; an independent study about student learning is forthcoming (Cavender et al. in preparation). Finally, we also asked our interviewees to comment on how Avida-ED affected teaching during Spring 2020 (the coronavirus pandemic, or COVID-19 pandemic) and their views of Avida-ED's utility in a remote teaching environment.

Overall, the Active LENS workshop series appears to have provided a successful platform for preparing instructors to implement Avida-ED. The study participants valued the overall experience of the workshop, were very pleased with the organization and content of the workshop, and praised the ready availability of support materials that simplified Avida-ED implementation in their classrooms. The interviews revealed that most of the instructors felt prepared to implement Avida-ED after the workshop; most of the study participants incorporated Avida-ED into their courses, as did the majority of the workshop attendees overall. We also

found a correlation between the stated learning outcomes of instructors using Avida-ED and the course types in which it was used. Study participants had mixed attitudes regarding the use of Avida-ED in remote learning environments, with instructor self-confidence having a large influence on its success in their own virtual teaching. Finally, the interviews illuminated for us areas where Avida-ED is an effective teaching tool, pointing the way towards its appropriate use, and showing us where further Avida-ED curriculum development might occur.

Methods

Ethical Approval Statement

All participants interviewed in this study provided voluntary consent and no financial or gift incentives were provided to elicit participation. Following a determination that its procedures and outcomes were all of minimal risk to participants, this study was determined to be exempt from additional review by MSU's Institutional Review Board.

Workshop Attendee Recruitment

We recruited attendees by advertising the workshop opportunity in online biology education forums and listservs. We also sent notices to the chairs of university biology departments located near the non-MSU hosting institutions, when workshops were held in those areas. Attendees applied online for specific workshops, answering questions about their learning goals and potential future use of Avida-ED. We encouraged applicants to apply in teams of two, to facilitate faculty interaction during the workshop itself and after returning to campus. The Active LENS project covered all invited attendees' workshop expenses.

Study Participant Recruitment

Two authors (BSG and JJS) recruited study participants from the complete register of Active LENS workshop attendees; this pool of individuals included anyone who attended an

Active LENS workshop from 2015 to 2019, who indicated they were course instructors, and who were not members of the Active LENS research team. Of the 110 total individuals who attended a workshop during this five-year period, 105 met these criteria (Table 1).

We divided all attendees into three subsets and then invited each attendee by email to participate in a remote interview. The subset first contacted (n=14) were instructors who had previously contributed data from their course implementations to a separate study related to using Avida-ED to address evolutionary misconceptions (Cavender et al. in preparation). The next-contacted group (n=14) were those who had remained in regular communication with Active LENS personnel, though who had not necessarily collaborated or participated in other ways. Finally, we contacted the remaining attendees (n=77). Those who did not initially respond to the first invitation email received one follow-up email again requesting their participation. Every invitation included the study's consent script as an attached file.

Of the 105 attendees, three could not be located and contacted by email. For the remaining 102, we received responses from 57. Our study participants are the 46 individuals who ultimately participated in a remote interview. All participants were instructors at institutions in the United States. Though we did not ask for participants' gender identities during interviews, we observationally identified 28 of the participants as women and 18 as men. Twenty participants later provided their gender identity when registering for the 2022 Active LENS Academic Congress; none of these responses contradicted our observations.

Interview Protocol

To develop our interview protocol, we relied on an iterative process; interviews conducted with study participants drawn from the first subset of the recruitment pool served as the primary sources for protocol adjustments (Ayres 2008). These adjustments were minor—

reordering topics of discussion and providing some additional specificity for clarity. Interviews from the second subset served as a test of the revisions and opportunity for potential further changes, should they have been needed (but were not). Our final interview protocol is included as Supplementary File 2. The protocol was designed for interviews of 40 to 60 minutes, beginning with background questions regarding participants' current place of work and position, their place of work and position at the time of their attendance of an Active LENS workshop, and a list of courses in which they used or considered using Avida-ED. Following these were open-ended questions about: their experiences at the Active LENS workshop they attended; their course-planning process regarding the aforementioned courses; and later, their institution's response to the COVID-19 pandemic and its effect on their teaching responsibilities. Because the protocol's adjustments were minor, the small differences between the first and final iterations are not likely to have led to significant interview experiences between participants from the first subset of invitees and everyone else.

The most time-intensive portion of the protocol concerned details about a participant's recollections of specific implementations of Avida-ED. In this study we consider as an "implementation" any Avida-ED use by a participant that occurred within a listed course at an established educational institution. Whenever possible, we collected the course's title, a short description, the number of students per section, the number of sections taught, and the general course schedule. We also included open-ended questions about the course's plan of Avida-ED implementation, the targeted learning goals meant to be addressed by Avida-ED (specifically asking about evolutionary concepts), the completion expectations for students' Avida-ED related tasks, any challenges that arose when implementing Avida-ED, how participants have adapted

their implementation plans for repeated iterations of a given course or for other courses, and how participants assessed student learning outcomes.

Interviews

Of the 46 study participants, two pairs of participants taught their courses jointly and so were interviewed together; the remaining 42 participants were interviewed individually. Each interview was approximately 45 to 60 minutes in duration. Two authors (BSG and JJS) utilized the semi-structured protocol to guide the conversation. We conducted these interviews remotely over a popular video conferencing platform. Each interview began with greetings and introductions, a reading of the consent script, and verbal confirmation of the participant's consent, before working through the protocol. Most participants agreed to additionally share digital copies of their course syllabi, their Avida-ED instruction and evaluation materials, and other documents relevant to their pedagogical use of Avida-ED.

Data Coding

BSG relied upon both his and JJS's contemporaneous interview notes to compile a confidential, standardized record for each participant to note portions of the interview responses and digital file contents that correlate to specific subjects from the protocol. (See Supplementary File 3 for an example record, shared with specific consent of the participant.) The record also lists all existing digital files associated with the interview, such as the researchers' interview notes, and any course syllabi or lesson handouts provided by the instructor.

This record primarily collates each participant's course load and implementations. For implementations, the record captures the first academic term of implementation, their course type, course level, number of course sections and enrollment, curricular details–such as number and duration of sessions, the lesson plan, and mode of instruction–implementation challenges,

and student learning goals, among other subjects. The diversity of learning goals, discussed below, was of great interest, so we spent significant effort on learning-goal-specific coding.

Learning-Goal Coding

Because learning goals were shared conversationally by participants, they were not standardized, so we developed a standardized code schema and defined five broad categories of codes (Figure 3, in Discussion below): Evolutionary Concepts, Nature of Science Concepts, Scientific Skills, General Skills, and Pedagogy.[2] For example, the code *natural selection concepts*, categorized within Evolutionary Concepts, was associated with participant-provided goals that referenced: understanding natural selection; random vs. directed mutations; natural selection is not random, but also not artificially directed; differences between mutation appearance and mutation persistence in a population; mutations are not directed; mutations are neither universally beneficial nor detrimental, but rather dependent upon environment-specific circumstances; and an intention for students to overcome existing misconceptions related to the other *natural selection concepts* goals.

To illustrate this learning goal coding process, the Avida-ED Lab Book (hereafter, lab book)[3] serves as a useful example. The lab book includes four model exercises that instructors could use or adapt when implementing Avida-ED as well as a final section about how to use Avida-ED for independent research projects. Though each exercise describes multiple learning

[2] It was beyond the scope of the current study to categorize learning goals with respect to specific misconceptions and their associated cognitive construals (e.g., teleological reasoning, essentialist thinking, and anthropocentric thinking) as defined by Coley and Tanner (2015). Instead, BSG relied on our schema to code each stated learning goal, for analysis.

[3] The Avida-ED Lab Book was developed and updated over time by the Active LENS Project curriculum development team. Because each workshop received a slightly different lab book version and past attendees were informed of lab book updates that they could freely access for ongoing instruction, we refer to all these versions collectively as the "lab book".

goals for students who work through it, each can be coded according to our schema. Since Exercise 1 is designed to convey the random nature of mutations, this is simply coded as such (*random nature of mutations*). Exercise 2 primarily intends to convey that mutations do not arise due to population need nor due to some directional force. We code this as *natural selection concepts*. Exercise 3 is about how evolutionary fitness is environmentally specific: a group of organisms that evolve to be fit in one environment may not be fit when transferred to another. We code this as *fitness concepts*. Exercise 4 covers the concept of genetic drift and other non-adaptive mechanisms of evolution. We code this as *genetic drift*. We categorize all four of these exercise-associated codes as Evolutionary Concepts. Finally, the Independent Research section of the lab book shows how instructors can broaden their implementation to other learning goals, including all those we categorize as either General Skills or Scientific Skills.

Results

Workshop Cohorts

Over the course of five years (2015-2019), the Active LENS team recruited eight cohorts for summer workshops. The 105 total attendees, 14 of whom identified as under-represented minorities, included 63 women and 42 men and hailed from 24 states. Their 56 diverse public (41) and private (15) institutions included all major Carnegie Basic Classification (Indiana University Center for Postsecondary Research n.d.). Ten attendees came from high school institutions and three came from institutions that conduct college preparation activities. Figure 1 includes a more detailed breakdown institution type together with the numbers of participants and their implementations.

Active LENS Experiences Described by Study Participants

Our protocol included prompts for any positive and/or negative feedback about participant experiences at the Active LENS workshop they attended. Overall, these responses were quite positive. Many spoke about enjoying the thoroughness of the workshop content with

Carnegie Classifications:

Institution Type	# Attendees	# Participants	# Implementations
Doctoral Universities: Very High Research Activity (R1)	30	12	14
Doctoral Universities: High Research Activity (R2)	8	3	5
Doctoral/Professional Universities (D/PU)	2	0	0
Master's Colleges & Universities: Larger Programs (M1)	17	8	13
Master's Colleges & Universities: Medium Programs(M2)	5	2	3
Baccalaureate Colleges, Multiple Foci	15	7	11
Mixed Baccalaureate/Associate's Colleges	2	1	2
Associate's Colleges, Traditional & Non-Traditional, Transfer & Career	15	7	10
Special Focus 4-Year Institution	*1	*1	*1

Other Institutions:

College Preparation	3	1	1
High School	*10	*5	*6

*One participant taught at two institutions

Figure 1.1: Number of Avida-ED implementations by Institution Type. Post-secondary institutions are classified by the Carnegie Classification, using the "Basic" descriptions. Additionally, implementations occurred both at the high school level, as well as in a college preparatory institution not classified by Carnegie.

respect to the design, function, and usability of the Avida-ED program. Participants also positively noted the time devoted to personal lesson design and presentation. In contrast, participants' attitudes towards the housing accommodations for the workshop period were more mixed. However, many did also mention the usefulness of the workshop for professional networking, including the fact that all were housed in the same location.

One ubiquitous response from participants regarded the usefulness of the lab book. Nearly every participant either directly noted the benefit of receiving the book during the

workshop and using it when learning about the software or spoke about using its exercises when designing or carrying out their implementation. About half (n=32) of the implementations used at least one unaltered lab book exercise and nine others used one or more altered exercises to meet the participants' curricular needs. No participants indicated any specific problems with the lab book exercises, though one high school instructor reasonably pointed out the need to rewrite the exercises using level-appropriate language for their classroom, given that the book was produced for introductory-level college biology courses.

Avida-ED Implementations Described by Study Participants

These next sections describe the implementations carried out by the study participants, including their institution types, course types and levels, and the learning goals that were addressed using Avida-ED. Implementations happened at a wide diversity of institutions, at all levels of high school and undergraduate biology instruction, and in courses with a wide range of course topics. Supplementary Table S1 lists all 66 implementations shared by participants. Table 2 presents a representative set of 10 implementations.

Institution Types

Of the 66 total implementations, 10 took place in Associate's Colleges, two in Mixed Baccalaureate/Associates Colleges, 11 in Baccalaureate Colleges, 16 in Master's Colleges and Universities, 19 in Doctoral Universities, one at a Special Focus Graduate Institution, and six in High Schools. One implementation occurred at a college preparation organization. The number of participants of each classification is reported in Figure 1.

Course Levels and Types

The courses for participant implementations varied widely, from introductory and upper division biology courses to a 400-level computer science course about Artificial Intelligence

Table 1.2: Representative Avida-ED Implementations in Courses Taught by Active LENS Workshop Attendees. For the full list of implementations, see Supplementary Table S1.

Participant	Course Type	Institution Type	Duration	Content
E	Intro Bio - Organismal	Associate's Colleges: Mixed Transfer/Career & Technical-High Traditional	Two lab class sessions	Exercises 3 & 4
F	Intro Bio - Cell and Molecular	Doctoral Universities: Very High Research Activity	One lecture class session	Exercise 3 - modified
M	Intro Bio - Non-majors	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	One Lecture Session	Exercise 1 (in support of Nature of Science)
OO	General Bio - 9th grade	High School	3-4 Class sessions	Exercise 1
DD	Evolution	Other	Parts of 3-4 90 minute class sessions	Exercises 1-3, then some competitions
FF	Evolution - 3xx	Doctoral Universities: High Research Activity	Three studio lecture sessions (2 hours each)	Self-produced lessons on Selection, Mutation, and Drift (Hardy-Weinberg Equilibrium)
KK	Genetics - 2xx	Master's Colleges & Universities: Larger Programs	One Lab Session (3h) plus required "Homework Lab"	Exercises 3 & 4 (for Pop Gen week)
"Rich" and "Daniel"	Microbiology Lab - 3xx	Doctoral Universities: High Research Activity	Extensive throughout semester	Intro, Exercises 1-4, three add'l Avida-ED exercises from website, plus self-produced phylogenetics exercise and bracketed head-to-head tournament
Z	Environmental Physiology - 3xx	Baccalaureate Colleges: Arts & Sciences Focus	One class session, one lab session	Introduction; Self-produced exercise on evolution of adaptations in animals
BB	Artificial Intelligence - 4xx	Master's Colleges & Universities: Medium Programs	One Lab Week	Exercises 1 & 2

Table 1.3: Aspects of the 66 Avida-ED implementations.

(a) Number of implementations at various course education levels.

Course Level	# Implementations
High School	6
College 1xx	32
College 2xx	3
College 3xx	10
College 4xx	10
ToT	2
Unspecified	3

(b) Instruction Duration. Numbers of implementations with three or more instruction sessions and research projects, broken down into the total number across all 66 implementations, the number of intro biology implementations, high school implementations, other (non-intro biology college courses, college preparatory courses, and Training of Trainer courses), and finally the number of implementations for which this information went unspecified.

	Total Known	Intro Bio	High School	Other	Not Specified
≥3 Instruction Sessions	24	8	6	10	6
Research Projects	14	4	5	5	3

(discussed below). Table 3a reports the numbers of implementations for each instructional level, from Grade 9 in high school to the highest undergraduate course level in US universities, as well as in Training of Trainers (ToT) educational settings.

Course types were more difficult to quantify, as most implementations fell into a minimum of two categories. For instance, one implementation occurred in a course categorized both as an Evolution course and as a Capstone course; two other Evolution courses were also labeled by participants as Population Genetics courses. One participant reported an implementation in an introductory course, with an emphasis on Allied Health concepts, which included both biology majors and non-majors. Figure 2 lists all course types, as well as the most common secondary types for introductory courses.

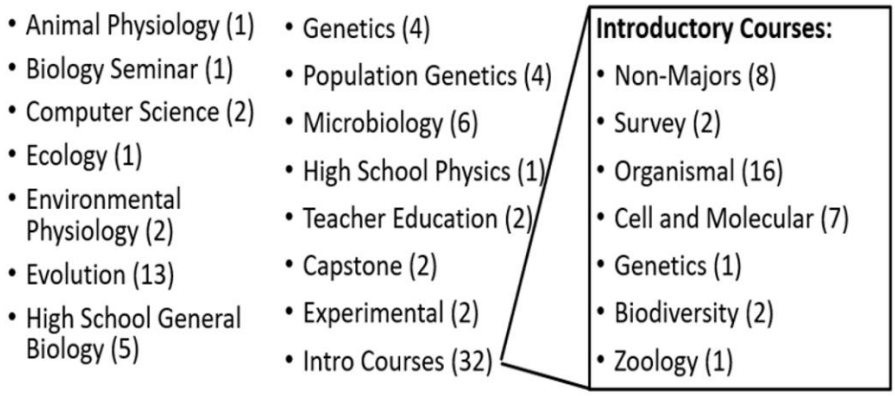

Figure 1.2: Avida-ED implementations by course type. Some implementations are counted under multiple topics (that total does not add to 66). Introductory course implementations are further broken down by their subtopics, where some once again fall under multiple topics.

Almost all (60) of the implementations occurred in college biology departments or by high school biology instructors, with Introductory Biology courses comprising almost half of all implementations (n=32; Table S1). At least 10 of the 13 Evolution courses were at the upper-division level or as degree program capstone courses; one other was a ToT K-12 pedagogy course focused on teaching evolution. (We did not capture the course level for the other three.)

Six implementations occurred in courses with a Microbiology focus, with one of these taught in a nursing program. Other notable types included Genetics (with two being the aforementioned Evolution and Population Genetics courses), Environmental Physiology, Microbiology, and Capstone courses. Five implementations were reported in high school level General Biology courses. One was at the 9th grade level, two as joint 9th and 10th grade courses, one at the 11th grade, and one Advanced Placement Biology course for the 12th grade.

Interestingly, an additional high school implementation–in a 9th grade physics course–was one of six implementations in courses taught outside of biology departments. The others were: a computer science course, which the participant described as "Biology-Inspired Computation"; another upper-division computer science course, on "Artificial Intelligence"; the aforementioned microbiology for nurses course; the aforementioned ToT evolution instruction course; and a ToT pedagogy certification course focused on high school Science Methods.

Of the 32 "Introductory Biology" course implementations, the most common course type, 23 occurred in a biology "Majors" sequence (which is typified by a two-semester series), an "Organismal" course (with content ranging from ecology and evolution to surveys of organismal diversity), or a "Cell and Molecular" course (with content focused on events at the cell and molecular level). In one case, a participant reported genetics as the topic for their introductory biology course. Another implementation occurred in an introductory course focused on "Allied Health" and designed for both majors and non-majors. Seven instructors implemented in introductory courses for non-majors.

The second-most common course type for implementation was "Evolution," including both a senior capstone course and a ToT pedagogy course for K-12 instructors. Of the evolution

courses for which instructors reported their course level, all occurred at the upper-divisional level, save for this ToT course.

Cessation of Implementations

All but four participants reported implementing Avida-ED initially and continuing to use it in subsequent terms of their instruction. Two participants explained their discontinuation of using Avida-ED. For May,[4] this was straightforward: she was a graduate student who, at the time of her attendance in Active LENS and up until the 2020 Spring term, had assigned teaching duties in her department. Her first implementation was a limited introduction to the Avida-ED software and a voluntary exercise which few students completed; given the lack of interest, May chose not to repeat this. Her second implementation–in a separate evolution course and repeated over multiple terms–was much more robust, with a self-produced introductory exercise and a second self-produced exercise to teach students about fitness landscapes. But when May received a doctoral fellowship that did not include a teaching assignment, she ceased implementing as she was no longer an instructor. However, we note that, after May moved on from teaching this course, another instructor–who was an Active LENS attendee but did not participate in this study–continued to incorporate Avida-ED into this second course.

The other participant to cease using Avida-ED explained a different scenario. After attending Active LENS with their department chair, Kali implemented in the organismal-oriented introductory biology sequence course in her department. However, after a few years (the exact number went unspecified) she stopped using Avida-ED because she found that student evaluations criticized the Avida-ED project. She also spoke about how, in her observation,

[4] We use pseudonyms for every named participant in this article.

students did not seem to learn the desired concepts as well through this participatory project, compared to lecture-based instruction.

Non-Implementation

Two participants reported not implementing Avida-ED in their classrooms. (There are several reasons why workshop attendees who did not implement Avida-ED might not want to join this study as a participant, which we expand upon below.) One of these, Rachel, attended a workshop that concluded two weeks prior to the start of the fall term at her institution, which she determined was not enough time to write an implementation into the course she would be teaching. She also noted several barriers that contributed to her not having implemented. These included: her impression of a steep learning curve for students, which would require significant instruction time for learning the software and thus larger project to justify the initial instruction; a dissatisfaction with the current curricula of her institution's two-course intro biology sequence and desire to fully redesign them, rather than merely a minor adjustment just to include Avida-ED; her institution's investment in other tools for instruction and lack of interest in Avida-ED; institutional budgetary concerns regarding computing equipment for student instruction; and her lack of course assignments over the next several terms due to an awarded research grant.

For Sofia, non-implementation was a consequence of her professional position in the years following her Active LENS workshop attendance. While still a PhD candidate, she was not in a position to add Avida-ED to the curricula of any courses with which she was associated. When interviewed, Sofia had since defended her dissertation and started a postdoctoral fellowship at another institution, but this fellowship did not include any teaching responsibilities. However, given her then-upcoming transition to a tenure-track position at a third institution, she

spoke at length about her planned course curriculum for an introductory biology lab course there, which would include an Avida-ED based research project.

Avida-ED Curriculum Types

We observed a wide range of Avida-ED implementations among study participants. The most frequently observed implementations were in Introductory Biology courses (n=32), which as a subset reflect the diversity observed among all reported implementations. Within this set, implementations mostly utilized one (n=10) or two (n=11) instructional sessions, while fewer (n=8) used three or more. (In three cases we were only made aware of the implementation's existence but did not capture their details.) With respect to instructional content, more than half (n=17) involved an introduction to Avida-ED followed by one or two exercises for exploring some aspect of evolutionary processes. Twelve intro biology implementations included three, four, or more exercises, including independent research projects or student evolutionary competitions (described below) in four introductory biology implementations. In contrast, five of the six high school implementations included a research component and all six used three or more instructional sessions. The counts of implementations with three or more instruction sessions, and those that included research projects, can be found in Table 3b.

One notable difference between the Introductory Biology subset and other implementations is that only four of the former included a large research or competition component outside of the instructional sessions, whereas ten non-Introductory Biology implementations included such a component, for a total of 14. This is mainly attributable to the fact that five of the six high school implementations included research components. Another difference is that there were more implementations of three or more instructional sessions in the full set (n=24) than either one or two-session implementations. Once again, this difference is

driven by the high school level, where all six implementations used three or more instructional sessions. The college-level implementations for which we captured numbers of instructional sessions (n=52) were nearly evenly split between one-session (n=16), two-session (n=18), and three-or-more-session (n=18) implementations.

Of all implementations for which participants described their curriculum (n=60), the majority (n=42) relied on at least one exercise from the lab book, either as written or with course-specific modifications; 19 used three or all four exercises from that text.

Learning Goals

Participants used Avida-ED to address a broad range of learning goals in their courses. We identified and coded 188 discrete learning goals, with each goal classified into one of the five broad categories described in Methods. While most of the goals mentioned by participants in their interviews were in the Evolutionary Concepts category (115/188 total, or 61.2%), Scientific Skills received 33 mentions (17.6%), Nature of Science Concepts received 31 (16.5%), General Skills received 7 (3.7%), and Pedagogy were mentioned twice (1.1%). Briefly, the most common codes were *natural selection concepts* (n=32), *random nature of mutations* (n=20), and *data management, curation, and presentation* (n=18). For the complete list of learning goal codes and their respective counts, see Figure 3 in Discussion below.

Dissemination

One key component of the Active LENS workshops was the direction to attendees to disseminate Avida-ED to other instructors, as these were ToT workshops. However, evidence from our interviews suggests this activity was not as widely pursued by attendees as was implementation. First, as a part of Active LENS workshops from 2016 to 2020 (with 2020 held virtually due to the COVID-19 pandemic), one or two members from a previous year's cohort of

attendees were invited back to present their implementation to the new cohort. This qualified as dissemination in this study. Nine attendees were invited back over this time period; all nine also participated in this study.

In response to a direct question about dissemination, 32 participants spoke about sharing knowledge of Avida-ED with other instructors or scholars. Eighteen of these indicated that their introduction of Avida-ED to other instructors was through some form of formal presentation to scholars or instructors, in many cases at academic conferences. Eleven described introductions of Avida-ED to their colleagues or other instructors via casual or informal conversations. Six participants described either helping their colleagues with implementing Avida-ED—whether a one-off circumstance, or by adopting Avida-ED as a part of the department's curriculum for a particular course regardless of instructor—or using Avida-ED in ToT course. Two participants additionally published journal articles about using Avida-ED.

In total, 35 participants either shared with us dissemination activities or did not share activities but returned to Active LENS the following year to present about their implementation.

Discussion

Below, we discuss what we learned by capturing descriptions of and characterizing the implementations of Avida-ED carried out by our study participants with respect to the different course types in which Avida-ED was used, the types of implementations produced, and the learning goals that instructors addressed via its implementation.

Participant experience at Active LENS

Overall, study participants communicated that the Active LENS workshops were of high quality and value to them. Among the themes that emerged from our conversations was that the workshop attendees appreciated that we provided them with ready-to-use curricular materials via

the lab book (described in Learning Goal Coding above), which we explored and unpacked together during the workshop sessions. For the most part, these required little modification in order to allow attendees to adapt them to their own teaching situation. They also appreciated that the provided materials were tried and true; the materials had been used by workshop facilitators in their own courses so that many of the potential pitfalls had already been discovered and addressed.

These ready-to-use materials mostly came from the lab book, which was mentioned by most participants as particularly valuable. Some participants adapted the materials for their particular courses. Commonly-shared changes involved modifying the language of a given exercise to make it more understandable for a particular instruction level, changing the text of the reflective questions at the end of each exercise to tailor these to their own students, and modifying the activities to align more closely with the participant's intended topic of instruction. No participants spoke about a need to adjust the Independent Research portion of the lab book in their research project implementations, owing to this section's wide adaptability to possible research topics.

Avida-ED Implementations

Participation in Active LENS workshops led to a broad and diverse set of Avida-ED implementations in classrooms across the US. Of the 46 Active LENS attendees who participated in our study, 44 (95.6%) implemented Avida-ED in their classrooms.

While we observed Avida-ED implementations at all levels of instruction (high school to advanced undergraduate) and in a wide variety of biology and other course types in our interviews, nearly half of them occurred in Introductory Biology courses (32/66 implementations, or 48.4%). In general, these implementations had short durations (one or two

class sessions), and addressed a narrower set of well-defined learning objectives, often guided by the lab book. The introductory biology implementations of Avida-ED often occurred in the lecture classroom instead of the laboratory, involved a small number of class sessions, and gave students the opportunity to interact with Avida-ED for a limited amount of time. Because of this, we consider that these implementations were of lower impact than those which implemented Avida-ED via more substantial periods of time, or as research projects in following with the lab book's final section. The former of these still represent meaningful implementations of Avida-ED in situations where longer-term or larger implementations would not be desired or even feasible; implementations as a research project align with what Lark et al. describes as "engaging students in authentic science practices" (Lark et al. 2018), (2018:82).

Lark et al. identifies uses of Avida-ED in authentic research as one of its highest impact uses (2018:84). Research using Avida-ED engages students in the complete set of science and engineering practices identified by NRC/NGSS from hypothesis generation and protocol development to experiment, data collection, analysis and presentation. (Kohn et al. 2018). Only 14 participants had their students conduct a full research project using Avida-ED. Somewhat surprisingly, high school was the instruction level with the highest concentration of participants who had students engage in Avida-ED based research: four of five high school instructor participants, and five of their six implementations. This may be due to the fact that the high school teachers that attended the Active LENS workshops tended to be extremely well informed and experienced practitioner, but it is more likely due to their having greater flexibility in the time they could allocate to it in their class compared to college instructors, such as those who incorporated Avida-ED into lecture courses without lab sections. The need to save time may also account for the fact that some instructors had their students generate their own research

questions, while others provided more guidance and even mandated choice of projects from a predefined list. Another likely reason is that many instructors simply had different learning goals for their courses. Avida-ED was designed to give users maximum flexibility for a wide range of learning goals related to evolution. Some instructors chose to use Avida-ED as a platform for a full independent student research project, but others used it for a more focused purpose, such as to illustrate a particular evolutionary concept in action or to provide hands-on experience of some scientific practice. This is borne out by analysis of our subjects' reported learning goals.

Learning Goals

The learning goals that we discuss here were self-reported by study participants and were coded by one of us (BSG), with the codes themselves being assigned to one of five categories

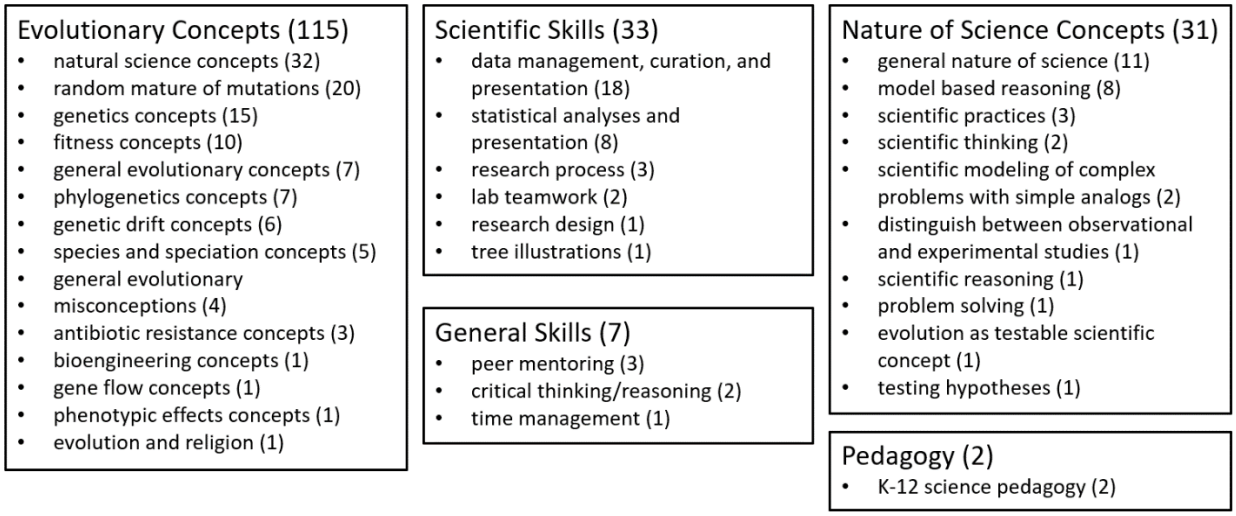

Figure 1.3: Categorization of learning goals. Reported learning goals were coded and placed into one of five categories as described in Methods. Figure shows the reported number of Avida-ED implementations that addressed each learning goal.

(Figure 3; also see Methods). Study participants reported learning goals related not only to evolution core concepts and misconceptions, but also pertaining to the nature and practices of science (Figure 3). It was beyond the scope of the current study to categorize learning goals with

respect to specific misconceptions and their associated cognitive construals (e.g., teleological reasoning, essentialist thinking, and anthropocentric thinking) as defined by Coley and Tanner (2015), but instructors no doubt had these in mind and they figured in the learning goals that are associated with the lab book exercises that many used.

Given that Avida-ED is a program designed primarily for teaching evolution, it is of no surprise that by far the most commonly-associated codes fell into the Evolutionary Concepts category, including the two most common codes: *natural selection concepts* (n=32) and *random nature of mutations* (n=20), which correspond to the second and first lab book exercises, respectively. Importantly, our code of *natural selection concepts* includes instances where instructors wanted students to understand the key differences between random and directed mutations, which is what distinguishes these from other cases where the instructor only expected students to learn about mutation randomness.

Somewhat surprisingly, the third-most commonly associated code was of goals related to *data management, curation, and presentation* (n=18), the most common of the goals categorized as Scientific Skills (n=33, or 17.6%). Another 31 goals (16.5%) were categorized as Nature of Science Concepts. This highlights that our participants relied on Avida-ED to incorporate not only evolutionary concepts but also general science concepts and practices, including skills important for scientific pursuits. Another surprisingly common learning goal code in our data is *genetics concepts* (n=15, 8.0%), particularly given that *genetic drift concepts*, the goal associated with the lab book's fourth exercise, was counted separately in our analysis (see Figure 3) and that genetics was not a common course type in which participants implemented Avida-ED. These unexpected learning goals highlight the adaptability of Avida-ED to a wide range of classroom circumstances.

Study participants incorporated about the same number of Nature of Science learning goals (n=31, or 16.4%) as Scientific Skills. The NRC Framework (2012) lists eight science practices that are core components of the Next Generation Science Standards (NGSS). These are: 1) Asking questions; 2) Developing and using models; 3) Planning and carrying out investigations; 4) Analyzing and interpreting data; 5) Using mathematics and computational thinking; 6) Constructing explanations; 7) Engaging in argument from evidence; and, 8) Obtaining, evaluating, and communicating information. Though participants may have been focused on evolutionary concepts as learning goals for their implementations, in using Avida-ED to achieve these goals, they also achieved several, if not most, of the eight NGSS science practices. Using Avida-ED as a research tool thus allows students to engage in all eight practices to an extent only limited by the design of the research experience. As Kohn et al. (2018) shows, using the first four lab book exercises will end up meeting seven of the eight NGSS core components, with only the first core component–"Asking questions"–de-emphasized or excluded. Having students engage in independent research projects after working through the four lab book exercises would incorporate "Asking questions" into the outcomes.

Example research implementation in an upper division Microbiology Lab course

Perhaps the most extensive implementation of Avida-ED shared by participants took place in a Microbiology lab course at an R2-classified institution. In this course, instructors Rich and Daniel had students work with Avida-ED throughout the semester, with explicit tie-ins to concepts in biological systems. In the first of three instructional units, Rich and Daniel introduced students to Avida-ED via a three-pronged approach. They introduced students to what Avidians are and how they work, relying on two videos about Avida-ED and digital evolution (Wiser 2016, Adami 2012), and then had students build a phylogenetic tree and read

Carl Zimmer's article in *Discover* magazine (2005). In Unit 2, they had students explore the random nature of mutation using Exercises 1 and 2 in the lab book and tied these to their lab activities carrying out the Fluctuation Test of Luria and Delbruck (1943). In Unit 3, students completed Exercise 3 and did Amy Lark's Fukushima Butterflies exercise (Lark et al. 2014), and Wendy Johnson's Evolution of TCE Biodegraders Exercise (Johnson et al. 2011b). Finally, Daniel and Rich worked out a genotype-to-phenotype exercise using *in silico* mutagenesis via systematic deletion mutations (genome engineering), which they paired with a CRISPR/Cas9 exercise in the wet lab. Their implementation culminated in a "March Madness"-style series of competitions, in which students evolved their own competitors for a tournament, which led to the crowning of a "champion" Avidian.

Non-Implementations and Cessations of Implementation

Participants who discussed either their discontinuation of implementation or their lack of implementation entirely, reported several direct barriers leading to these outcomes, reported above. These indicate a number of broader issues which may hamper an instructor's successful and sustained implementation of Avida-ED. There were several parallels between Kali's and Rachel's contexts that speak to these barriers. For one, Kali's department chair settled on a different computer program for teaching similar concepts in similar courses at their institution. Similarly, Rachel informed us that her department was already invested in other teaching tools and showed little interest in switching to Avida-ED. For another, Kali could not implement Avida-ED in the lab portion of the introductory biology sequence because the lab is standardized for the whole department and the other instructor responsible for teaching this course did not agree to use it. Rachel also could not persuade fellow instructors of standardized courses to change them by incorporating Avida-ED. Finally, at the time of Kali's first implementation,

Avida-ED was not yet a browser-based program. This technical limitation meant it had to be installed on each machine used for the implementation, which limited its use to university-owned laptops since the process of installation on student-owned laptops, if students had one at all, was too varied and complex to guarantee. Rachel similarly found too much complexity with the program, with its steep learning curve, as a similar technological barrier to its use.

Both Sofia and May were graduate students at the time of their Active LENS workshop attendance, and both struggled with the limitations of that status when trying to implement. May described one of her implementations as essentially a failure, given her inability to require participation by her course section's students; Sofia did not have any courses at all in which she could have tried to implement Avida-ED. However Sofia had already reported to us her upcoming position with teaching responsibilities, and May shared her intentions to pursue a career in the academy; both of these participants might very well successfully implement Avida-ED in their future teaching positions. Sofia, May, Rachel, and Kali all had difficulty with institutional constraints; none of them were in a position to affect change within their respective departments.

Dissemination

Despite the likelihood that this study's participants would be more likely than the average attendee to disseminate Avida-ED to other instructors, the evidence of dissemination in this study was also somewhat disappointing. Our original intent in the Active LENS workshops was that we would be "training-the-trainers" who would go forth and multiply the number of Avida-ED implementers. While there were notable exceptions in this area, (for example, one study participant produced a set of YouTube videos teaching people how to use Avida-ED), we hoped that our workshop attendees would do more. While not formally studied, we suspect that

we put too much of the responsibility for this endeavor in the hands of the participants, without providing appropriate structure and guidance.

Limitations

Research team members have had more regular communications with more of this study's participants than all attendees in general and those who were in more regular communication were more likely to be active users and disseminators of Avida-ED. Conversely, those attendees who did not ultimately implement Avida-ED after attending a workshop may have been discouraged from participating in this study, given that implementation and dissemination was one of the stated expectations of workshop attendance. In these senses our study sample is biased toward Avida-ED activity.

Nearly all of our study's participants (n=44, or 95.7%) implemented Avida-ED in at least one of their courses. However, for the above reasons, we expect that this is an overestimate of the overall rate of implementation, as those who agreed to participate in the study were probably more likely to have implemented Avida-ED. If we instead incorporate reports from and about other Active LENS attendees obtained outside of this study's interviews, we estimate that 62 (59.0%) of the 105 workshop attendees implemented Avida-ED (Table 1). This figure however is a likely underestimate, as we were not able to communicate with all of the workshop attendees who did not participate in our study. Realistically, therefore, the rate of implementation among all Active LENS attendees is somewhere between these two values. Instead, this discrepancy highlights the limitation of our study, which is an outcome of our non-random participant recruitment process: our results are not representative of all Active LENS attendees because our participants are not a representative sample.

Finally, we collected our data using the semi-structured interview process, chosen for its ability to facilitate a conversational style of interview among interviewers and interviewees while still allowing for some control of the topics by interviewers (Ayres 2008). One limitation of this method is the likelihood that an interview might progress in such a way that some subjects are not captured with as much depth as others, with these discrepancies remaining undiscovered until long after the interview has concluded and often during the data analysis phase. In this study, our interviews captured only partial information about eight implementations and this affected our analysis in two instances: our quantification of Evolution courses at the upper-divisional level; and the durations of implementations in Introductory Biology courses. Additionally, it is not possible to determine how many implementations were conducted by our participants but omitted entirely from their interview responses. For these reasons we are careful to explain that our analyses are only derived from implementations for which we have all of the relevant information for the given focus and we note how many of the relevant implementations have been excluded. In cases where we included all implementations in our analysis, we had captured all the information relevant to the subject.

Conclusions and Future Directions

Avida-ED is an engaging and effective tool for teaching evolution and the nature of science. In the 15 years of its development, it has achieved wide usage; server logs from the last eight months alone show that it has been accessed from 48 of the 50 US states, plus the District of Columbia and from 75 different countries. This study suggests some factors that might be addressed to further extend its use by overcoming barriers to adoption and implementation. One of our study participants commented that Avida-ED is a bit “scary” upfront for new adopters. Instructor content knowledge, pedagogical content knowledge (PCK), and technological

pedagogical content knowledge (TPCK; see Lark et al. 2020) are all required to some degree to use Avida-ED effectively in the classroom. This study showed that faculty development workshops are an effective way for instructors to gain such knowledge and skills to implement this experimental platform in their own classes, but that for many instructors more is needed before they are ready to train others. A Training of Trainers model is a promising approach, as evidenced by participants who succeeded in disseminating Avida-ED beyond their own classrooms, but it sets a higher bar that requires greater preparation and support. For instance, we expect that supplemental instructional and help videos that participants could access as refresher materials would assist their ability and confidence for dissemination, so we have begun to create and make these available. Lessons learned from this experience will help improve ToT workshops in the future.

Declarations

Availability of data and materials

The coded dataset supporting the conclusions of this article is included within Supplementary Table S1. This dataset has been deidentified to conserve confidentiality for study participants. The original interview audio recordings will not be made available.

Competing interests

No authors of this study have a competing interest to declare.

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Authors' contributions

BSG and JJS conducted the remote interviews. All authors contributed to the study design, data analysis, and manuscript authorship, including the design of all figures. All authors reviewed the manuscript.

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Additional Files referenced in this manuscript:

- Supplementary File 1 is Appendix A
- Supplementary File 2 is Appendix B
- Supplementary File 3 is Appendix C
- Supplementary Table S1 is Appendix D

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APPENDIX A: SUPPLEMENTARY FILE 1 – SAMPLE ACTIVE LENS WORKSHOP SCHEDULE

The following file has been significantly altered due to the decisions made by the department responsible for reviewing dissertation formatting at Michigan State University. To view the correct version of this file, please find this online as a supplementary file to the publication, at https://doi.org/10.1186/s12052-024-00211-2.

Active LENS Workshop - Michigan State University – Wednesday Schedule

- 8:30 - Workshop Overview & Avida-ED 101 – Rob Pennock
- 10:00 – Break
- 10:15 - Working Session: Exercise 1 – Mike Wiser
- 11:15 - Experimental Evolution – Rich Lenski
- 12:15 – Lunch
- 1:15 - Working Session: Exercise 2 – Jim Smith
- 2:00 - Digital Evolution – Charles Ofria
- 3:00 – Break
- 3:15 - Working Session: Exercise 3 – Jim Smith
- 4:00 - Working Session: Exercise 4 – Louise Mead
- 5:00 - Working Session: Developing Avida-ED Research Questions – Rob Pennock
- 6:00 - Free time/travel to restaurant
- 7:00 - Dinner @ San Su (Hannah Plaza, 4750 Hagadorn Rd.**)**

Active LENS Workshop - Michigan State University – Thursday Schedule

- 7:30 - Breakfast on your own.
- 8:30 - Backwards Design: From Learning Goals to Implementation & Assessment – Jim Smith
- 9:30 - Working Session: Develop Learning Goals & Your Avida-ED Lesson Plan
- 10:30 – Break
- 10:45 – Experience of last year's participants– Shannon McDermott (Central Virginia CC)
- 11:45 – Lunch
- 12:30 - QUBES and the Avida-ED FMN, Active LENS Assessment Study & Expectations – Louise Mead
- 1:30 - Working Session: Assessment strategies and meshing lesson plans with project research
- 2:45 – Break

- 3:00 - Education Research Findings Thus Far – Mike Wiser
- 3:30 - Working Session
- 4:30 - Avida-ED 4.0 preview & Plans for Friday – Diane Blackwood, Rob Pennock
- 5:15 - Free time/ travel to restaurant
- 6:00 - Dinner @ Brody Square (241 W Brody Rd (at Harrison Rd. Rm 200)
- 7:00 - Team Working Sessions on your own

Active LENS Workshop - Michigan State University – Friday Schedule

- 8:30 - Team Presentations (15 min slots)
- 10:15 - Break
- 10:30 - Team Presentations (15 min slots)
- 11:30 - Instructor Survey
- 11:45 - Wrap-up
- 12:15 - Box Lunch
- 1:15 - Optional – Presentations of last year's teams
- 2:30 – Adjourn

Workshop Participants will:

- Gain familiarity with and fluency in working with the Avida-ED platform;
- Learn about the theoretical underpinnings of digital evolution as well as the empirical research in bio/computational evolution being conducted by the BEACON Center for the Study of Evolution in Action;
- Design, develop and present a proposal for the implementation of an Avida- ED lesson set the following academic year;
- Implement their proposed plan in their Fall or Spring course (with assistance of the workshop facilitator team via video conferencing consultations, who will help overcome hurdles encountered in the implementation plan);
- Assess student learning outcomes using assessment tools designed in consultation with the Avida-ED team;
- Develop and implement an educational and/or outreach event for High School biology teachers or the general public at their home institution;
- Share their results and experiences with one another and make plans for on-going efforts in the follow-up workshop

APPENDIX B: SUPPLEMENTARY FILE 2 – INTERVIEW PROTOCOL

Interview Protocol – "Active LENS: Learning Evolution and the Nature of Science Using Evolution in Action – Instructor Implementations"

Background Information:
(we have name)
Position Title (may have this)
Institution of Employment/Enrollment at time of workshop attendance
Current Institution of Employment/Enrollment
Courses taught for which you have considered using Avida-ED, including institutions, departments, and curricula descriptions, and general descriptions of students

General Expectations and Experiences:
How did you first hear about Avida-ED? How did you first hear about the Active LENS workshop?
Did anything from the workshop experience surprise you?
How did the workshop influence your plans for the aforementioned courses, prior to teaching them?
By virtue of your experience with Avida-ED, do you know of other instructors who have begun or tried using it? What did that look like?

Teaching and Outcomes:
Do you remember what your expectations were of the courses where you implemented Avida-ED? What were these?
How did you plan to implement Avida-ED?
What configuration did you use (in-class, homework, individual, group, whole-class, etc.)?
How, if at all, did your implementation deviate from your plans?
What challenges arose, even if they did not lead to a deviation from your planned implementation?
If you have taught any additional courses since that first one, how did you alter your plans for using Avida-ED in these subsequent courses?
What other tools do you use to teach evolution to your students?
What role does Avida-ED play in your overall strategy to teach evolutionary concepts to your students?

Assessments
The Avida-ED Active LENS team shared with you some pre- and post- course assessment tools. How did you use these? For instance, were students graded for them or given extra credit?
Was the post-assessment before, after, or a part of your final evaluations for students? What form were those other final assessments in?

Do you plan to continue using Avida-ED?

Pandemic:

Did you use Avida-ED in any capacity in a course during the Spring 2020 or Summer 2020 terms? Did you have to shift this course to remote learning at any point, either before or during the term?

When in the timeline of your Avida-ED project did this shift in the curriculum occur (not the date, but rather the instruction/activity)?

Are you using Avida-ED in a remote learning context now? What changes have you made?

What are your thoughts about using Avida-ED in a remote learning context?

No Implementation (or Implementation Abandonment)

Background Information:

(we have name)

Position Title (may have this)

Institution of Employment/Enrollment at time of workshop attendance

Current Institution of Employment/Enrollment

Courses taught in which evolution or nature of science topics are covered, (or any others in which you think Avida-ED might be useful)

General Expectations and Experiences:

How did you first hear about Avida-ED? How did you first hear about the Active LENS workshop?

Did anything from the workshop experience surprise you?

How did the workshop influence your plans for the aforementioned courses, if at all?

By virtue of your experience in learning about Avida-ED, do you know of other instructors who have begun or tried using it? What did that look like?

Teaching and Outcomes (if used but then removed from curriculum):

Do you remember what your expectations were of the courses where you implemented Avida-ED? What were these?

What configuration did you use (in-class, homework, individual, group, whole-class, etc.)?

How, if at all, did your implementation deviate from your plans?

What challenges arose, even if they did not lead to a deviation from your planned implementation?

For not using Avida-ED, or after stopping using it:

Can you tell me about your reasoning for choosing to not use Avida-ED (or not continue using Avida-ED)?

What were the barriers for you regarding Avida-ED, such as institutional support, difficulty with the technology, in-class instruction concerns, etc.?

What other tools do you use to teach evolution concepts, or the nature of science, to your students in the aforementioned classes?

Assessments

What assessment tools do you use to gauge learning outcomes for your students?

Do you have any plans to revisit Avida-ED for potential use in your curriculum?

Pandemic:

Did you have to shift any of your aforementioned courses to remote learning in Spring 2020? What did that look like for your circumstances?

Are you currently teaching in a remote or hybrid environment? What does that look like at your institution?

What digital tools are you using for your remote or hybrid instruction, whether for delivering course content or assessing students' learning outcomes?

APPENDIX C: SUPPLEMENTARY FILE 3 – EXAMPLE CODING INSTRUMENT

The following file has been significantly altered due to the decisions made by the department responsible for reviewing dissertation formatting at Michigan State University. To view the correct version of this file, please find this online as a supplementary file to the publication, at https://doi.org/10.1186/s12052-024-00211-2.

Return to Log List
Interview Code:
82369542a
Active LENS Workshop:
2016 MSU
Active LENS Workshop:
2016 MSU
Expertise:
Microbiology; evolutionary biology
Institution Type:
Master's Colleges & Universities: Larger Programs
Institution/Position During Workshop:
Doctoral Universities: High Research Activity; Post-DoctoralPosition
Current Position:
Assistant Professor; Department of Biology
Partnered Colleague Interview Code:
53956124a

Workshop or Avida-ED positives:
Was able to learn from the experts themselves. Could work on projects right there with input from peers and experts; put a plan in place. Activities were already developed for them and ready to use; went through these as students.
Workshop or Avida-ED negatives:
None shared

Courses Where Considered Using Avida-ED:
Course Title/Description:
Upper-level microbiology course with partner at first institution
Course Number:
BIO 325
Used AvidaED:
Yes
Course Title/Description:
General Microbiology (infectious diseases) at first institution
Upper-level microbiology course with partner at first institution
Course Number:

300-level
Used AvidaED:
No
Course Title/Description:
General Microbiology at current institution
Course Number:
BIO 214
Used AvidaED:
Yes (brief)
Course Title/Description:
Pathogenic Microbiology at current institution
Course Number:
BIO 314
Used AvidaED:
No

Promotion of Avida-ED to Others:

No promotion activities while at current institution. (Would require introducing a new perspective).

The bracket competition event at first institution was held as a party open to the larger academic community, so everyone who attended or participated was introduced to Avida-ED.

First Course Implementation:
Course Type:
Microbiology – 3xx (Lab) at first institution
Term of First Implementation:
Spring 2017
Weekly Class Lecture and/or Lab Schedule:
Lab, two meetings per week, 3 hours each (from 53956124a)
Number and Size of Sections:
2 sections, 12 per section
(from **53956124a**)
Implementation Plan:

Class implementation was also discussed in **53956124a**. Their involvement with this class was specifically for a portion of the implementation—a single-elimination bracket competition—that this instructor came up with when attending the Active LENS workshop. Talked with the colleague who attended the session with them about competition idea and realized, setting up different envronments at different stages of a bracket tournament shows how fitness isn't in static environment. They together discussed which specific environments to use. First thought maybe to make it completely random; second to make it pre-determined. Ended up doing "random" setup to determine which resources were present and which mutation rate would be used.
(from 53956124a):

- Pairs evolved organisms from Tuesday to Sunday, submitted a zipped Avidian file with a description of genome sequence, fitness under no-resources, fitness under all-resources,

and function list. Could make 10 'genetic edits' to engineer. Info submitted via Google Form.

- Submissions were seeded based on info provided. Round 1 was 1000 cycles, parents spawned next to children.
- Round 2 was 1000 cycles with different environment (changing resources and mutation rate)
- Students had to make matchup predictions and then evaluate those predictions.

Students specifically prepared for future matchups where the environments weren't known. Students had to decide whether or not to perfect first environment, or try to guess the future environment and/or try to optimize for more environments. Each student had to fill in their predictions for the competition bracket. Each student saw the fitness of each Avidian in the first environment, for a no-resource environment, and for an all-resources environment. After first round, students were asked to update bracket for their predictions for second round, after they got the infor for the second round environment.

Students quickly saw that an Avidian they thought would do really well wasn't going to do well, once they saw the next environment setup.

Learning Goals:

- Evolutionary concepts:
  - antibiotic resistance; evolution; bioengineering
- Nature of science:
  - model-based reasoning

Expectations:

Hoping that students would understand that fitness is not a fixed metric by virtue of doing competitions under different circumstances (environments and mutation rates).

Assessments Used (including Active LENS):

Students kept a notebook in which they reflected on the outcomes of each round and their predictions. Were asked which rounds had the best conditions, and why.

Students filled in and submitted a worksheet with prompts to respond to, but this instructor did not share details with us.

See **53956124a** for more on assessments.

Challenges:

There is a learning curve to Avida-ED and to overcome this you need to devote time, energy, and effort to this.

Changes Made (during term or subsequent terms):

None discussed in this interview (see 53956124a for changes after this instructor's departure).

Subsequent Terms of Implementation:

Spring 2018 (see **53956124a** for further adjustment and implementation in Spring 2019 without this instructor.)

Second Course Implementation:

Course Type:

Micriobiology – 2xx at current institution

Term of First Implementation:

Fall 2020

Weekly Class Lecture and/or Lab Schedule:
Lecture; has multiple lab sections taught by many instructors. No schedule shared
Number and Size of Sections:
110 students
Implementation Plan:
Briefly used as an example of digital organisms:
The week's topic was microbial evolution. First introduced the MEGAplate (Kishony 2016) experiment case study, to let students observe evolution in real-time. Second case was citrate evolution in an E. coli experiment. Then introduced Avida-ED as an example of digital organisms, where the rate can be turned up even faster.
Learning Goals:
- Evolutionary concepts:
  - mutation; mutation rate; variation
- Nature of science:
  - Model-based reasoning

Expectations:
None discussed
Assessments Used (including Active LENS):
None discussed
Challenges:
Lab content is set by lecturer, but requires getting all lab instructors up to speed on anything being used.
For using A-ED, there is too much ground to cover and the students would need too much lead time to get to a point where Avida-ED was of use to them.
Changes Made (during term or subsequent terms):
n/a

Pandemic Response:
At current institution:
First week of March was when university realized the seriousness. Made decision not to bring students back while they were on Spring Break. Made decision immediately, for remaining of the semester. Gave everyone 2 weeks after spring break canceled, to allow faculty time to redesign the remaining weeks of courses.
In summer, they decided to announce going entirely remote—first in the state, very early in country—to give faculty and students a heads up in what they're getting into. Synchronous and asynchronous was up to faculty. Hybrid in-person could be granted for upper-level is needed and could adhere to guidelines. Will again be remote all of Spring.

Notes:
Teaches a BIO 110 lab, that lab covers the scientific process in its first lab, through evolution. Use phylogenetic trees to pick things up. The content is set by the lecturer. There's 12 instructors for 20 lab sections.
Regarding Single-Elimination Bracket idea:

Students had option to "intelligently design" their Avidian, or to select them via evolution. They included this option to highlight the efficiency of selection over design. This was at the university where the biggest name in Intelligent Design was working for a while.

One objective is to eventually write up the competition project for publication.

Links to Appendices:

Interview Recording
First Interviewer Notes
Second Interviewer Notes

Documents Provided:

- None

APPENDIX D: SUPPLEMENTARY FILE 4 – SUPPLEMENTAL TABLE 1 – AVIDA-ED IMPLEMENTATIONS BY ACTIVE LENS PARTICIPANTS

The following file has been altered due to the content decisions made by the department responsible for reviewing dissertation formatting at Michigan State University. To view the correct version of this file, please find this online as a supplementary file to the publication, at https://doi.org/10.1186/s12052-024-00211-2.

Supplementary Table S1: Data.

Study Participant	Course Type	Institution Type	Duration	Content (Lab Book)
A	Intro Bio - Allied Health (Majors and Non-majors)	Baccalaureate/Associate's Colleges: Associate's Dominant	One Week (Two Lab Sessions, 2h each)	Exercises 1-3
B and C	Intro Bio - Cell and Molecular	Doctoral Universities: Very High Research Activity	Parts of two lecture sessions (Intro and then Debrief)	Exercise 1 (mod)
D	Intro Bio - Cell and Molecular	Doctoral Universities: Very High Research Activity	Parts of two 2.5h studios sessions	Introduction; Exercise 1 (modified) with QBio emphasis
E	Intro Bio - Cell and Molecular	Associate's Colleges: Mixed Transfer/Career & Technical-High Traditional	7 lecture sessions	Intro; Exercises 1-4
E	Intro Bio - Cell and Molecular	Associate's Colleges: Mixed Transfer/Career & Technical-High Traditional	Two lecture class sessions	Exercises 1 & 2
F	Intro Bio - Cell and Molecular	Doctoral Universities: Very High Research Activity	One lecture class session	Exercise 3 - modified
G	Intro Bio - Cell and Molecular	Doctoral Universities: Very High Research Activity	Single 80 min class session (modeling exercise)	Self-produced lesson focused on random nature of mutation

Supplementary Table S1 (con't)

H	Intro Bio - Cell and Molecular	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	Three lab sessions (3h each)	Exercises 1-3
I	Intro Bio - Genetics	Baccalaureate Colleges: Arts & Sciences Focus	One Lab Session (3h)	Exercise 1
J	Intro Bio - Non-majors	Doctoral Universities: High Research Activity	Not Specified	Not specified
K	Intro Bio - Non-majors	Associate's Colleges: High Transfer-High Traditional	Single 2h Lab Session	Exercises 1 & 2
L	Intro Bio - Non-majors	Doctoral Universities: Very High Research Activity	One lecture session	Exercise 3 (modified)
M	Intro Bio - Non-majors	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	One Lecture Session	Exercise 1 (in support of Nature of Science)
A	Intro Bio - Non-majors	Baccalaureate/Associate's Colleges: Associate's Dominant	Not Specified	Not Specified
F	Intro Bio - Non-majors (Survey)	Doctoral Universities: Very High Research Activity	One lecture class session	Exercise 3 - Modified
N	Intro Bio - Non-majors (Survey)	Baccalaureate Colleges: Diverse Fields	Two Lab Sessions (3h each)	Exercises 1-3
O and P	Intro Bio - Organismal	Master's Colleges & Universities: Larger Programs	Two Lab Sessions (3h each)	Introduction; Exercises 1 - 4
J	Intro Bio - Organismal	Doctoral Universities: High Research Activity	Not Specified	Not specified
Q and R	Intro Bio - Organismal	Doctoral Universities: Very High Research Activity	Single 2h discussion section	Self-produced exercise on relative nature of fitness
B and C	Intro Bio - Organismal	Doctoral Universities: Very High Research Activity	Parts of four lecture sessions (Intro and then Debrief for each Exercise)	Exercise 1 (mod); Exercise 2 (mod)

Supplementary Table S1 (con't)

S	Intro Bio - Organismal	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	Four 3h lab periods; multi-week investigation	Exercises 1-4; Independent Research Project
E	Intro Bio - Organismal	Associate's Colleges: Mixed Transfer/Career & Technical-High Traditional	One lecture session and multiple (unspecified) lab sessions	Reintroduction and independent research project.
E	Intro Bio - Organismal	Associate's Colleges: Mixed Transfer/Career & Technical-High Traditional	Two lab class sessions	Exercises 3 & 4
May	Intro Bio - Organismal	Doctoral Universities: Very High Research Activity	One lab class, one section	Voluntary introductory exercise
F	Intro Bio - Organismal	Doctoral Universities: Very High Research Activity	One lecture class session	Exercise 3 - modified
U	Intro Bio - Organismal	Associate's Colleges: High Transfer-High Nontraditional	Two Lab sessions of 2.5h each	Introductory Lesson; Self-produced lesson on mutation/viability
Kali	Intro Bio - Organismal	Master's Colleges & Universities: Larger Programs	Three class session of 50 min each	Exercises 1-3; Battle Royale
M	Intro Bio - Organismal	Associate's Colleges: Mixed Transfer/Career & Technical-Mixed Traditional/Nontraditional	Two Lab Sessions (2h each)	Exercises 1-3 (NOS and Evolution concepts)
W	Intro Bio - Organismal	Baccalaureate Colleges: Arts & Sciences Focus	Three Class Sessions (80' each)	Exercises 2 & 4; Self-produced Phylogeny Exercise
X	Intro Bio - Organismal (Biodiversity)	Baccalaureate Colleges: Diverse Fields	Two lecture class sessions	Exercise 1; Self-produced exercise on role of mutation in innovation
I	Intro Bio - Organismal (Biodiversity)	Baccalaureate Colleges: Arts & Sciences Focus	Four Lab Sessions (3h each)	Exercises 1-3, plus some competitions

Supplementary Table S1 (con't)

Y	Intro Bio - Organismal (Zoology)	Doctoral Universities: High Research Activity	Two Lab Sessions (3h each). During pandemic, first lab in-person and second	Exercises 1-4
Z	Animal Physiology - 3xx	Baccalaureate Colleges: Arts & Sciences Focus	Two lab sessions	Introduction; Self-produced exercise on evolution of adaptations in animals
AA	Biology Senior Capstone Seminar	Baccalaureate Colleges: Arts & Sciences Focus	Parts of first 14 of 40 class sessions	Self-produced lesson set focused application of scientific reasoning to solving problems
BB	Computer Science - 4xx (Artificial Intelligence)	Master's Colleges & Universities: Medium Programs	One Lab Week	Exercises 1 & 2
BB	Computer Science - 4xx (Biologically-Inspired Computation)	Master's Colleges & Universities: Medium Programs	One Lab Week	Exercises 1 & 2
CC	Ecology - 3xx	Baccalaureate Colleges: Arts & Sciences Focus	Four lecture class sessions	Exercises 1 & 2 (HW); Design and test hypotheses
Z	Environmental Physiology - 3xx	Baccalaureate Colleges: Arts & Sciences Focus	One class session, one lab session	Introduction; Self-produced exercise on evolution of adaptations in animals
R	Environmental Physiology of Animals - 2xx	Doctoral Universities: Very High Research Activity	Two class sessions to begin semester	Exercise 2 (modified); distinguish between mutations occurring and resistance evolving
DD	Evolution	Other	Parts of 3-4 90 minute class sessions	Exercises 1-3, then some competitions

Supplementary Table S1 (con't)

W	Evolution	Baccalaureate Colleges: Arts & Sciences Focus	Four Class Sessions (80' each); Multi-week Research Project	Exercises 2, 3 & 4; Self-produced Phylogeny Exercise; Proposal/Poster Presentation
EE	Evolution - 3xx	Master's Colleges & Universities: Medium Programs	Parts of three class sessions supporting lectures	Intro exercise; Exercise 1, 2, & 3 (mod)
Min	Evolution - 3xx	Doctoral Universities: Very High Research Activity	Two lab classes sessions (3h each)	Self-produced Introduction to Avida-ED, and Fitness Landscape Exercise
FF	Evolution - 3xx	Doctoral Universities: Very High Research Activity	Three studio lecture sessions (2h each)	Self-produced lessons on Selection, Mutation, and Drift (HWE)
J	Evolution - 4xx	Doctoral Universities: High Research Activity	Not Specified	Not specified
GG	Evolution - 4xx	Master's Colleges & Universities: Larger Programs	Two class sessions plus independent research project	Intro, Exercises 1 - 3 as homework; Independent Research
Z	Evolution - 4xx	Baccalaureate Colleges: Arts & Sciences Focus	1 lecture class session, 1 homework exercise	Self-produced intro, self-produced take-home exercise.
HH	Evolution - 4xx (Experimental)	Master's Colleges & Universities: Larger Programs	Not Specified	2 Exercises (genetic drift exercise and then 'natural selection exercise')
II	Evolution - Capstone	Master's Colleges & Universities: Larger Programs	Four Lecture Sessions (partial) in support of evolution concepts; Research Project	Exercises 1-3, plus self-produced Phylogeny Exercise (see G); Research Project

Supplementary Table S1 (con't)

JJ	Evolution and Population Genetics - 3xx	Master's Colleges & Universities: Larger Programs	Five lecture class sessions (first a half-day)	Self-produced intro and Exercises 1-4
JJ	Evolution and Population Genetics - 3xx (Lab)	Master's Colleges & Universities: Larger Programs	Semester-long research project	Independent research
KK	Genetics - 2xx	Master's Colleges & Universities: Larger Programs	One Lab Session (3h) plus required "HW Lab"	Exercises 3 & 4 (for Pop Gen week)
Daniel	Microbiology - 2xx	Master's Colleges & Universities: Larger Programs	One course period	Program introduction
HH	Microbiology - 3xx	Master's Colleges & Universities: Larger Programs	Two class sessions	Self-produced exercises focused on mutation and strength of selection
Rich and Daniel	Microbiology - 3xx (Lab)	Doctoral Universities: High Research Activity	Extensive throughout semester	Intro, Exercises 1-4, three add'l Avida-ED exercises from website, plus self-produced phylogenetics exercise and bracketed head-to-head tournament
HH	Microbiology - 4xx	Master's Colleges & Universities: Larger Programs	Not Specified	Not Specified
HH	Microbiology - 4xx (Experimental)	Master's Colleges & Universities: Larger Programs	Not Specified	2 Exercises (genetic drift exercise and then 'natural selection exercise')
F	Microbiology - Nursing	Doctoral Universities: Very High Research Activity	One lecture class session	Exercise 3 - modified

Supplementary Table S1 (con't)

GG	Teacher Educaton - Evolution Pedagogy for K-12	Master's Colleges & Universities: Larger Programs	Unspecified number of sessions, in a 5-day all-day course.	Not specified
NN	Teacher Education - Science Methods Teaching Certification	Special Focus Four-Year: Other Special Focus Institutions	2 of 7 class sessions, unspecified length	Avida-ED lesson design for project-based science course
NN	High School Bio - 11th grade	High School	Every class session for three weeks (90 min 4x per wk)	Independent Projects Self Designed
OO	High School Bio - 9th grade	High School	3-4 Class sessions	Exercise 1
PP	High School Bio - 9th/10th Grade	High School	5 90-minute sessions over one week.	Self-produced Research Cycle.
PP	High School Bio - AP-Bio	High School	Five 90 minutes class sessions	Self-produced Research Cycle
QQ	High School Bio - 9th/10th Research	High School	As HW with multiple in-class discussion as support throughout semester	Exercises 1-4; Research Project
RR	High School Physics - 9th grade	High School	Every day for 2h/d for 2 weeks	Intro and Exercises 1-3; Scientific Thinking focus; Research projects

MANUSCRIPT TWO: EDUCATIONAL TRAINING OPPORTUNITIES IN KENYA'S TECHNOLOGY SECTOR: QUALITATIVE DATA COLLECTION REPORT

Forward

This chapter is a demographic data-only internal report I wrote for the World Bank's Gender Innovation Lab (GIL), regarding an exploratory study in Kenya about women's access to training resources for the country's technology sector. During the design phase of the study, I met routinely with social scientists at the GIL to set the study's parameters, including the expected number of interviews and focus groups, general demographics of those to be included in the research activities, the selection of a Kenyan research assistant, and the semi-structured protocols for both the interviews and focus groups. While designing the project, the researchers and I spoke at length about the theoretical perspectives informing our decisions, which I briefly cover in this forward.

We took as our starting point Andrea Cornwall's critique of development via a feminist lens, which calls out such endeavors for falling short of what's necessary to address the power imbalances at the core of what is to be developed (Cornwall 2003). Cornwall argues for a more inclusive participatory endeavor: "The challenge is to hold together—rather than dispense with, or completely erase—a politics of difference that is premised on the contingent, situational identity claims that make an identification with 'women's issues' possible, with a politics in which identifications provide the basis for action on commonly held concerns" (Cornwall 2003, 1338). This critique provided an excellent opportunity to pursue an intersectional approach to the study. There is not enough space here to thoroughly discuss *intersectionality* and its roots in Black feminist thought or the coinage of the specific term in Crenshaw (1989).

However, to provide a working definition of the term, Hill Collins and Bilge (2016) assert the following as a largely-accepted:

> Intersectionality is a way of understanding and analyzing the complexity in the world, in people, and in human experiences. The events and conditions of social and political life and the self can seldom be understood as shaped by one factor. They are generally shaped by many factors in diverse and mutually influencing ways. When it comes to social inequality, people's lives and the organization of power in a given society are better understood as being shaped not by a single axis of social division, be it race or gender or class, but by many axes that work together and influence each other. Intersectionality as an analytic tool gives people better access to the complexity of the world and of themselves. (Hill Collins and Bilge 2016, 2)

When turned critically toward the wide diversity of feminisms and their respective movements, intersectionality provides the opportunity to engage with and alleviate or eliminate many of those movements' shortcomings, particularly with respect to specific oppressions. To follow with bell hooks' expansive definition of feminism, it is ultimately "a movement to end sexism, sexist exploitation, and oppression" (hooks 2015, viii).

Levendowski directly characterizes hooks' definition as intersectional feminism and illuminates what it brings to bear upon the challenges of oppression: "oppression comes from many sources and [intersectional feminism] provides a framework for addressing the oppression of people with overlapping identities, such as Black women, queer women, disabled women, poor women, women crime victims, women across these identities, and *even oppressed people who are not women at all*" (2022, 804; emphasis added). Levendowski notes, "intersectional feminism is expansive; it arguably threatens to swallow all equitable movements. But a broad approach is crucial to realizing that equity for women that fails to dismantle oppression broadly reflects a privileged and partial feminism" (Levendowski 2022, 804). Thus, for me, the core of intersectional feminism is this: all oppressions are intertwined, such that one or even many cannot be brought down permanently without taking them all down eventually.

The study was designed specifically to explore the potential multiple facets of marginalization in Kenya's tech sector, by collecting more than simply participants' gender

identity, but their ethnicity, age (which is a common hierarchical identity among some communities in the country), and religious affiliations.

The data-only report is reprinted here with permission from Rachael Pierotti, Senior Social Scientist in the Gender Innovation Lab, Africa Region Office of the Chief Economist, World Bank Group.

Project Summary

This qualitative research project, on "Educational Training Opportunities in Kenya's Technology Sector," was a preliminary investigation of the beliefs and perceptions that young, technology-oriented Kenyans have about the technology sector, to learn more about the drivers of the gender imbalance in participation in the sector. The study focused upon understanding the main reasons for why women and men do or do not choose to pursue careers in the sector, why women and men do or do not enroll in coding bootcamp programs offered by private companies, and the perceptions that young people have regarding women who are pursuing careers in the sector. This preliminary research is exploratory and is intended to continue in the near future in order to inform an intervention on women's participation in private coding bootcamps in Kenya.

Qualitative data collection was conducted through semi-structured interviews and focus group discussions with participants recruited through a for-profit company that offers coding bootcamps and other forms of information technology instruction – recruitment and instruction events, as well as through personal contacts of the data collection team. Data was collected in Nairobi and at nearby universities.

Personnel and Training

The qualitative research was supervised by social scientists with the Gender Innovation Lab at the World Bank. Work in the field was overseen by Brian Samuel Geyer (myself), a

research collaborator from Michigan State University. I designed the research protocol and data collection tools with input from the Lab's social scientists.

I conducted the initial phase of the qualitative research alongside a Kenyan research assistant. The data collection during this period consisted of (a) observations of four distinct technology-related events, (b) 16 one-on-one interviews, and (c) two focus group discussions. Following my departure from Kenya on October 27th, the Kenyan researcher conducted an additional 10 one-on-one interviews. Although having had extensive qualitative research experience, for the purposes of this specific project the Kenyan researcher engaged in a three-day training focusing upon techniques of qualitative methods, including event observation; semi-structured interviews; the fundamentals of probing during interviews and focus groups; the iterative process and its relation to this study's design; and the process of obtaining informed consent for participation and interview recording. The training also included discussions around the parameters of this study, the key rationales, and quality of note-taking during observations, interviews, and focus groups.

I was contracted for 15 days of work in Nairobi, while the Kenyan researcher completed a total of 40 days, inclusive of activities related to recruiting participants; conducting observations, interviews, or focus groups; and transcribing audio recordings of interviews and focus groups.

Data Collection Methods and Execution

Qualitative data collection was conducted from the second week of October to the second week of December, 2018. To recruit participants for the one-on-one interviews and focus group discussions, we used a snowball sampling method. We began by attending and observing recruitment and training events at the for-profit company; we then recruited participants for

follow-up interviews from the attendees at these events. Because fewer women were in attendance at events overall compared to men, we approached nearly every woman from each event for recruitment; we included fewer men from these events (see Table 1). We relied upon snowball sampling with initial participants to assist in recruitment; they reached out to their friends and colleagues to participate in interviews and group discussion. We also utilized the Kenyan researcher's personal contacts to recruit participants from a nearby university in Nairobi. Finally, the Kenyan researcher advertised our study via community-managed online groups and neighborhood organizations.

Participant Recruitment

The first interviewees, who were recruited from attendees of observed events, are noted under the row 'Events' in Table 1. Participants recruited through referrals from other participants fall under "Participant Referral." Those recruited through the Kenyan researcher's colleagues, friends, and acquaintances are noted under "Personal Contacts." Finally, several contacts were recruited via community-managed Facebook groups, Whatsapp chat groups, and via word-of-mouth in a neighborhood in Nairobi; these participants are reported under "Community Advertisement." Upon completion of the Focus Group Discussions (see "Participant Demographics" below), only women were recruited for participation in order to emphasize their perspective. This is why no men were recruited via "Personal Contacts" or "Community Advertisement," which were later strategies used for recruitment.

Table 2.1: Participant Recruitment Methods.

Method	Men	Women	Total
Company Events	6	4	10
Participant Referral	5	11	16
Personal Contacts	0	5	5
Community Adverts	0	5	5
Total	11	25	36

Demographic Characteristics

Event Attendees

The majority of those in Kenya's technology sector – both as established professionals and university students – are men. This imbalance was apparent at three of the events we observed, reported in Table 2. The most-attended of these was a computer programming "Hackathon" on October 13th, a competition at which attendees received basic instruction on how to analyze provided data (given by sponsoring companies) within a period of time. Attendees openly collaborated on their code submissions. Of the 55 attendees at the event, 12 were women, the rest men.

University students in subsequent interviews reported that in their programs there are a substantially lower number of women than men.

Table 2.2: Attendees at Observed Events by Gender.

Event Name	Men	Women	Total
Hackathon	43	12	55
Management Panel	6	11	17
Facial Recognition	16	4	20
Design Thinking	7	1	8

The 'management panel' event differed from the other three events, given that 11 women attended compared to 6 men. This particular event was at a different location from the other two, in another part of the city. Additionally, the subject matter of the event was quite different from the others: in the other events, attendees were listening to presenters describe technological tools and techniques, whereas the management discussion panel involved questions from a moderator and the audience on subjects related to tech business management, hiring practices, and talent retention techniques.

Participants

Because the eventual intent is to improve women's participation in Kenya's technology sector, we made a concerted effort to interview more women than men during this exploratory period. In this study participants were not meant to be representative with respect to gender, age, ethnicity, or religious affiliation. The majority of participants are university students and therefore presumably younger than those currently working in the industry. Additionally, many of the participants we recruited later in the data collection period, through already-participating individuals, personal contacts, and word-of-mouth (snowball method), likely created homogeneity within the sample; in other words, ethnic background and religion may not be as diverse as is the true population of university students studying IT or tech-related fields. With these notes in mind, the following Tables 3 through 6 show the characteristics of participants with respect to these different traits.

Table 2.3: Interviews and Focus Groups by Gender.

	Men	Women	Total
Interviewees	6	20	26
Focus Group Participants	6*	5	11*
Total	11	15	36

*One group participant also interviewed

Given this study's interest in understanding barriers to women's participation in the tech sector, we interviewed more women than men. Most women were recruited because of their enrollment in a degree program related to the tech sector, such as Information Technology or Computer Science. Only one was from a degree program not commonly associated with the sector, which is biochemistry; she was recruited as a participant in the observed Hackathon.

Table 2.4: Interviews and Focus Groups, by Gender and Ethnicity.

Ethnicity	Men	Women	Total (%)
Kikuyu	8	4	12 (33.3)
Luo	0	9	9 (25)
Luhya	1	4	5 (13.9)
Kalenjin	1	3	4 (11.1)
Kamba	0	2	2 (5.6)
Meru	0	1	1 (2.8)
Pari	1	0	1 (2.8)
Nkole	0	1	1 (2.8)
Unknown	0	1	1 (2.8)
Total	11	25	36

Kenya's most recent census in 2009 reported the five most populous ethnicities as Kikuyu (17.1%), Luhya (13.8%), Kalenjin (12.9%), Luo (10.5%), and Kamba (10.1%). The ethnic diversity of the participant population is over-represented with Kikuyu and Luo, an underrepresentation of Kamba, and with Kalenjin and Meru represented at expected levels. Additionally, one woman and one man are immigrants from Uganda and South Sudan, respectively.

Table 2.5: Interviews and Focus Groups, by Gender and Age.

	Men	Women	All
Max Age	27	28	28
Min Age	19	18	18
Mean Age	21.2	20.2	20.5
Participant Total	11	25	36

Most of the participants were between the ages of 19 and 23, with a mean age of 20.5, which is to be expected for university students. Five 18-year-old women were included in this study because they were still in Secondary school, though they were old enough to participate. The oldest woman, 28, was also the only participant to be married, have any children (two), and be employed full-time; she previously completed a degree in marketing at a university. The oldest man, 27, was not married and did not have children, but did have a personal business and

was only enrolled at a university part-time, in order to complete a previously-started finance program.

Table 2.6: Interviews and Focus Groups, by Gender and Religion.

Religion	Men	Women	All
Christian: Catholic	7	2	9
Christian: Protestant	3	11	14
Christian: Unknown	1	10	11
Atheist	0	1	1
Unknown	0	1	1

The majority of the participants identified as Christian of some kind, with one who was not asked and one who reported being Atheist. Participants were asked for their religious affiliation in order to gauge whether or not there might be an issue for some in attending tech-related events on Saturdays, if they were practicing Seventh Day Adventists or affiliated with some other group who worshiped that same day. Every respondent who identified as an unspecified Christian also clarified that they worshiped on Sunday. Almost all of the Catholic participants were men and almost all of the Protestant participants were women.

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APPENDIX A: INTERVIEW GUIDES

Note: Interview and focus group guides were used by the data collection team as starting points and were meant to prompt general topics of discussion. They evolved over the course of the data collection period and have been further adjusted since my departure.

Topics for Interview with Participants Recruited via Snowball

Interview Length: 1 to 1.5 hours

1. **a. Warm-Up**. Interviewer: After reading through the consent form, start with a warm-up that lasts for at least five minutes. The warm-up is a chat about absolutely anything; it's a friendly way to get to know one another before you dive in into the interview. The warm-up is a way to establish rapport, and it is to your discretion about what to chat.

   b. Interviewer: Okay, thank you for all that! I am curious to know about your day yesterday. Would you walk me through it, and tell me everything that you did? You can start with the time you woke up, and what you did next. Interviewer, this is another way to continue with warm-up and to establish rapport. You should also feel free to talk about yourself at any time, as yet another way to establish rapport.

2. Interviewer: Great! [Add conversational note here about their previous response, to maintain the engagement.] I'm also interested in knowing a bit about your educational history. For instance, I'm wondering what year you are in at your university? Interviewer, you should gather this information, and ask these questions, in a way that flows conversationally, so that the communication exchange is less like a structured interview and more like a conversation. We are interested in knowing the following information:

   - Why did she choose their program/career?

- Why did she choose universities/colleges/schools?
- Why did she take the route they describe? (and probe, see 4a below)

3. **a.** Interesting! Now, how did you come to be interested in this program in your university? What was your path to this decision? Tell me more. Why did you end up in this program, or choose this program, and not others? Interviewer: Be sure to find out what the place of role models was –who influenced or helped her along the way? Were these friends? Parents? Teachers? Neighbors? Anyone else? Be sure to find out the story about how they were helpful. We need to know more than an answer such as 'friends.' Probe.

b. What are some of the challenges that you currently face in this type of work, or in the university program? What else? Tell me more about that. How do deal with those challenges? What else can you tell me about the challenges? Can you give me an example of this challenge? When was the last time you had to deal with this challenge? What happened? What did you do? Tell me more. Probe.

c. Thank you for telling all that. Now, I'm interested in learning about who are some of the people you talk to you in your program. Who do you talk to in your program? Would you tell me about them? Are these other female students? What about other male students? Please tell me about them. How did you meet them? How often do you talk to them? Why? Tell me all about them. Do you consider some of them to be friends? What was the last conversation you had with someone in your program? Please describe it to me, as I am curious. Interviewer: ask the respondent to tell you all about the conversation, as it is related to her program or anything else. Probe. Ask follow up questions that interest you.

d. Interviewer: Continue on with this topic of conversing with others. We'd like you to find out about a recent conversation the respondent had about how to get the right skills for a job in the future, as well as about future job opportunities. You should word the questions on this below in a way that makes sense to you. Examples of how to ask are as follows:

i. Thank you for explaining all of that to me. Now, staying with the topic of conversations, I'd like you to take a moment to think about the last time you spoke with someone about what is needed in order to get a job in the future. [Interviewer, allow her the time she needs to think about this conversation.] Once you're ready, would you be willing to share with me that conversation? Who did you have it with? When did you have it? What is it that you talked about? Why? Probe. Ask follow-up questions.

ii. That's so interesting! What about future job opportunities, more generally? When was the last time you spoke with some about that? Who was this person? When did you have that conversation? Would you be willing to share with me that conversation? What did you say to each other? Why? Probe. Ask follow-up questions.

4. **a.** I appreciate all that you've shared with me. Now, I'm wondering whether you've ever attended any events held by a private training company?

- If so, what and where was the event?
- Why did you decide to attend? [Interviewer: PROBE. Ask follow-up questions. Such as: What did you like about it? What did you not like about it? Etc.]

- What other events, anywhere, have you attended? Why did you attend these? [Interviewer: PROBE. Ask follow-up questions.]
- How did you hear about this event or events? [Probe. If the respondent says “my friend” or a family member, for instance, ask her how her friend found out about it. Or, if she says, “I found out about through AI Kenya” for instance, find out where she say the advertisement for AI Kenya. Also, what is AI Kenya? PROBE.]
- What do you think are some of the challenges that you or other people have to be able to attend these events? Why? Please tell me more about that. Probe.
- Can you describe for us what you thought about the event? Probe. Describe in detail.

b. To help inform the design of the intervention, we want to know about how the respondent generally accesses information about opportunities for events, trainings, etc. in tech. Does she feel in the 'loop'? Who is in the 'loop'? Is she overloaded with info and invitations to events/trainings and need to sort through to find the good ones? Or, are these opportunities somewhat rare? What kinds of advertisements tend to catch her eye? What does she look for? Ask these questions in a way that mimics a natural conversation.

5. **a.** What does your family think about your career in technology? Why do you think that each of your family members thinks this way? [Probe.]

b. What do your parents do for work? What about your siblings? [Probe.]

6. What do your friends think about this kind of career? [If they say any have strong opinions, ask why they think their friend has those opinions. These can be either positive

or negative. Probe. If the respondent says they like it because she can do computers, probe to see if there are any friends who do not support, and why. Probe.]

7. Thank you. Now I want to know more about women in your program, or women in general in IT/tech/ICT. First, can you tell me something about the number of women compared to men in your program (university, private training, etc.)?

- Why do you think these numbers are the way they are? Tell me more. [Interviewer: If the respondent does not know, ask her why she thinks this might be the case. She must have some ideas.]
- Why might women choose or not choose this career? Tell me more. [Probe.]
- Why might men choose or not choose this career? Tell me more. [Probe.]
- What do you yourself think of these reasons, for both women and men? Please tell me more. Why do you think this? [Probe.]
- Do you think that women and men in tech careers do equally well? If not, why not? Tell me more. Probe.

8. Ah, okay, thank you for that. Now, I am curious to know, do you work anywhere? If yes, what do you do? [Describe in detail. Probe.]

Perceptions about IT/ICT employment

9. **a.** What kinds of IT/ICT jobs are available? [Interviewer: Here we want to know from the respondent the kinds of jobs that they think are available. Get the respondent to describe them. Please get a list of sub-specialties in the field of IT.]

b. What type of person does well at those jobs? Or, put another way, who is best suited for each type of IT job? [Interviewer: Probe.]

c. What work or job would you like to do in the future? Why this job and not another? Tell me more. How likely do you think it is that you'll get this job in the future? Why? Tell me more. Do you yourself know anyone who has this kind of job? Tell me more. [Probe.]

d. Thank you for telling me all that. I appreciate your time. Now, I'm also very interested in understanding more about coding in particular.

If the respondent is in the field of IT but has decided to pursue a sub-specialty that is not coding, why not coding? What do they think of careers in coding? Ask in a way that is conversational, find out the answers to these questions as you see best.

In a way that seems natural for you, ask: What exposure have you had to coding? How much coding experience do you have? Has anyone ever tried to convince her to try coding or to get further training in coding? Why or why not? Do you like coding? Why or why not? Tell me more.

This is very helpful to know! Now, I'm wondering whether you've ever attended an event, or a training, or an info session about coding? Tell me about that [if yes]. If no, ask: Would you attend? Why or why not? Tell me more.

Now, I'm curious to know what you think about women who enter into coding? Are they different from other women who study IT? Why or why not? Do you yourself know any women who being trained in coding, or who now work in coding?

What do others think of women who choose coding?
(We want to know how young people perceive IT/ICT careers, and how they are gendered. This pertains to general impressions of people who work in IT/ICT, different stereotypes of people in different IT-related jobs, what IT-ICT jobs are like, what IT/ICT training is like in terms of required skills and the training environment, what kind of people excel at IT/ICT, how friends and family respond to women who choose IT/ICT careers, what challenges are specific to women in IT/ICT. We also want to hear about the stereotypes and observe social dynamics that occur when people debate stereotypes.)

10. Background Interviewer: Get the following information:

- Name, age, children, married, range of ages of children
- religion/denomination
- where staying near to Nairobi
- Home Area:

- Other than English and Kiswahili, what languages were you speaking when growing up?
- What languages did you speak at home when growing up?
- What is your mother-tongue?
- (as a follow-up to the initial, if tribe/ethnicity is still ambiguous) What is your father's/mother's mother-tongue?
- (as a follow-up to the initial, if tribe/ethnicity is still ambiguous) What language did your parents (the people you lived with) speak to you when growing up?

To complete, be sure to thank her for her time!

Topics for Post-Event Interview with Participants

Interview Length: .75 to 1 hours

1. Background:
    - Name, age, children, married, range of ages of children
    - religion/denomination
    - how far gone in school, describe secondary, diploma, degree information, including schools
    - Why chose programs, why chose universities/colleges/schools, why!
    - currently in school or not
    - where staying near to Nairobi
    - Home Area:
        - Other than English and Kiswahili, what languages were you speaking when growing up?
        - What languages did you speak at home when growing up?
        - What is your mother-tongue?
        - (as a follow-up to the initial, if tribe/ethnicity is still ambiguous) What is your father's/mother's mother-tongue?
        - (as a follow-up to the initial, if tribe/ethnicity is still ambiguous) What language did your parents (the people you lived with) speak to you when growing up?
        - Ask after any current employment
2. How did you discover this event?
    - found online: where did you find online
    - told by someone else: ask how they know that person

- if found out via email: who sent them the email
- if from social media: did you see it from a friend, a group, a company page, or something like that?

3. Why did you end up deciding to attend the Hackathon?
4. Is this your first Hackathon? What other events have you maybe attended? Why? Do you know of any challenges other people have to be able to attend these events?
5. Can you describe for us what you thought about the event?
    - What were you expecting for this event? Why were you expecting them?
    - Did anything surprise you about the event? Why?
    - Can follow with questions about challenges at this event
6. Remind them about Alfred calling people attending, "techies." If they don't know the term, you can define for them as these kinds of people who are working in computer programming, who are working in IT (information technology), who are often using social media, things like that. Then ask, how they've come to be in this kind of work, or come to decide to do this kind of work? Can try to follow-up about role models, if it comes up.
7. Ask about becoming trained for this kind of work. What other possible ways were there to get this training? Why did you pick this way?
8. Ask about what their family thinks about a career in technology?
9. Ask what friends think of this kind of career?

APPENDIX B: FOCUS GROUP GUIDE

Topics for Focus Group Discussions with University or Bootcamp Students and Friends

Discussion Length: .75 to 1.5 hours

Pre-Discussion Demographic Form:

Name:_____ Age:____ Gender: _____

Married (circle): Yes No Number of Children:____

Religion:_____ Name of Church/Mosque/Temple:_____

Current University Program:_____

Name of Past Colleges/Universities:_____

Name of Secondary School:_____

Mother-Tongue:_____ Home Area:_____

Discussion Subject Guide:

1. Go around for each participant to give their name, their current program and year number, or – for those who might not be in university or a training program – what kind of work they are currently doing.
2. Ask participants how they know each other. When did they first come to know each other? What kinds of things do they like to do when spending time together? What do you discuss when together?
3. For university students, what led them to go to university, instead of say finding work? Ask if others in the group have similar reasons. If any have different reasons, ask them to explain.

4. For students of any kind, ask how their program generally runs. What do they like about the program? What things might be better if they were done differently?
5. How did participants choose their career? For students studying in something that's in tech, how did you think of this path originally? Where did the idea come from? For others, what other paths did they consider?
6. For friends not in tech, what do you first think when your friend said they were going into this career?
7. What kinds of people choose to go into a career in tech? Why do you think they choose this career? What might keep people from choosing to go into tech? What might keep women from choosing to go into tech?
8. For all participants, do they have any family members who are also in the same career? Did they speak with this person about the career before choosing it? What did they talk about?
9. Do they have any family members who work in tech (including IT or ICT, or computer science {specifying these because some people might not know which kinds of careers are in tech})? If so, in what ways did this person influence their career choice?
10. Is the work done in tech careers all that important? If so/not so, why? Did participants think of these reasons when deciding whether or not to choose tech as a career, if at all (it's ok if they didn't)?

APPENDIX C: CONSENT FORMS

Interview Consent Form

Hello, my name is _____ and I am one of a group of interviewers working on a research project for the World Bank and [private for-profit company]. I am visiting you today because you have been invited to participate in a study that we are currently conducting about science and technology in Kenya. The objective of this study is to better understand how bootcamps, science and technology, and training in these areas operate in Kenya. We aim to help improve women's and men's opportunities for tech jobs in the future. Today, we would like to hear more about your experiences in your own words.

The questions we will ask you today concern your demographic background, your experiences with recruitment (and training) with [the private for-profit company] or any other tech school, as well as other areas of your work life and your future. Certain questions may touch upon sensitive subjects. The total duration of the interview should be less than 90 minutes. Though you will not directly benefit from this study, it will not negatively affect you either. If it is alright with you, the interview will be audio recorded so that what you say will be accurately reported and will contribute effectively to this study.

All of your responses will be kept strictly confidential and only the managers of this project (at the World Bank, not at [the company]) and the research team will have access to data that could identify you. Accordingly, all information collected today, including all audio recorded, will be anonymized and no one who sees the resulting data will be able to know that it was you that gave these responses. In particular, no employees of [the company], and other science and technology training providers, will have access to any data that could identify you.

Your participation is purely voluntary, and if you refuse to be interviewed there will be no consequences for you. If you do choose to participate, you reserve the right not to respond to certain questions if you would prefer. You may also interrupt the interview at any time. A member of the research team may return in the future, but you can choose not to participate in the follow-up interview if you wish.

This project is led by [social scientists] at the World Bank Gender Innovation Lab (GIL). If you have any questions, you can reach [the lead GIL researcher] by email at [email redacted], [the secondary GIL researcher] by email at [email redacted]), Brian Geyer, the in-country researcher, at [private Kenyan phone number and email address redacted] or [the Kenyan researcher] at [Kenyan phone number and email address redacted]).

After participating in this interview, I can provide you with a 250-shilling airtime card from either Safaricom or Airtel.

Your collaboration is important to enable this project to be realized and I thank you for your participation on behalf of our entire team.

Do you have any questions concerning the conditions of this interview?

Do you consent to participate in this interview? (If NO, end the conversation. If YES, conduct the interview.)

Focus Group Consent Form

Hello, my name is _____ and I am one of a group of interviewers working on a research project for the World Bank and [private for-profit company]. I am visiting you today because you have been invited to participate in a study that we are currently conducting about science and technology in Kenya. The objective of this study is to better understand how bootcamps, science and technology, and training in these areas operate in Kenya. We aim to help improve women's and men's opportunities for tech jobs in the future. Today, we would like to hear more about your experiences in your own words.

The questions we will ask you today concern your demographic background, your experiences with recruitment (and training) with [the private for-profit company] or any other tech school, as well as other areas of your work life and your future. Certain questions may touch upon sensitive subjects. The total duration of the focus group discussion should be less than 90 minutes. Though you will not directly benefit from this study, it will not negatively affect you either. If you agree with it, the discussion will be audio recorded so that what you say will be accurately reported and will contribute effectively to this study.

All of your responses will be kept strictly confidential and only the managers of this project (at the World Bank, not at [the company]) and the research team will have access to data that could identify you. Accordingly, all information collected today, including all audio recorded, will be anonymized and no one who sees the resulting data will be able to know that it was you that gave these responses. In particular, no employees of [the company], and other science and technology training providers, will have access to any data that could identify you.

Your participation is purely voluntary, and if you refuse to participate in discussion there will be no consequences for you. If you do choose to participate, you reserve the right not to respond to certain questions if you would prefer. You may also interrupt the discussion to leave at any time. A member of the research team may return in the future, but you can choose not to participate in the follow-up interview or discussion if you wish.

This project is led by [social scientists] at the World Bank Gender Innovation Lab (GIL). If you have any questions, you can reach [the lead GIL researcher] by email at [email redacted], [the secondary GIL researcher] by email at [email redacted]), Brian Geyer, the in-country researcher, at [private Kenyan phone number and email address redacted] or [the Kenyan researcher] at [Kenyan phone number and email address redacted]).

After participating in this interview, I can provide you with a 250-shilling airtime card from either Safaricom or Airtel.

Your collaboration is important to enable this project to be realized and I thank you for your participation on behalf of our entire team.

Do you have any questions concerning the conditions of this interview?

Do you consent to participate in this interview? (If NO, dismiss the individual from the discussion. If YES, conduct the focus group with those who remain.)

MANUSCRIPT THREE: GENDER NORMS AND ATTITUDES AMONG KENYA'S TECH SECTOR PROFESSIONALS

Abstract

Kenya's technology sector may provide insight into currently-held gender norms in Kenyan society and illuminate the ways in which these norms have continued shifting as the country becomes more digitally connected to the global West. Recent acceleration in internet access has the potential to affect a shift in the country's gender norms, as Kenyans see increased digital access to media, entertainment, and social media in the global West. In this study, I investigate existing gender norms among members of Kenya's technology sector professionals, including those working in the sector as well as those in related educational programs. Participants shared with me their attitudes and beliefs about working in the tech sector, including certain gender norms and attitudes that are commonly held in Kenyan society. They discussed with me their own perspectives regarding these norms, as well as the shifts they see taking place, which I present within the context of participants' gender identities. Future research about Kenyan gender norms would benefit from an intersectional approach to participant identities, to build a more robust understanding of these norms from the perspective of several different identities.

Introduction

"Okay, I don't do skirts. I don't do dresses. I don't do high heels," Sonya[1] tells me bluntly as we sit on a covered platform, in a quiet Kisumu, Kenya, neighborhood on a hot, sticky Friday afternoon in early March. "I do tomboy styles more—not even more, I do it. I feel it's more

[1] All participant names in this article are pseudonymous. Many participants chose their own pseudonyms, though some have been assigned names because they either did not choose one for themselves, or the one chosen was too personalized to effectively mask their identity.

comfortable. Like, hey, skirts—I just feel like, [whistles], the air is going everywhere!" To close out our interview, Sonya wanted to share with me an issue she had with another student of the women-only web development course she was taking – and from which I recruited her for this interview – who she had overheard speaking ill of her when the other student was unaware of her presence. "She doesn't want to talk to me" Sonya added, explaining that her lack of adherence to specific attitudes about how women should dress was the central issue of their conflict.

Kenya's technology sector may provide insight into currently-held gender norms in Kenyan society and illuminate the ways in which these norms have continued shifting as the country becomes more digitally connected to the global West. By 2017, almost 90% of Kenya's households had access to a cell phone, with the number of internet subscriptions in the country – whether via those cell phones or a home internet connection – had reached 30 million (Nyabola 2018, 36). The COVID-19 pandemic spurred an acceleration in broadband and fiber optic home internet connections in the country. Fiber optic internet first reached Kenya via an underwater cable in 2009, with four cables connected to the county by the end of 2012, and by 2018 had been upgraded to supply approximately 18 terabits per second (Tbps) of connection, combined (Submarine Network, n.d.-a; n.d.-b; n.d.-c; n.d.-d). The two cables added in 2021 and 2022 nearly quadrupled this throughput by adding an additional combined 52 Tbps (The Star Staff 2022). By the time of my arrival for data collection in 2021, my fiber optic home internet connection tested as significantly faster than any non-fiber optic broadband connection my friends and colleagues in the US had access to, at a price that was reasonable for the budget of a middle-class Kenyan family. With such robust connections, Kenyans were able to stream entertainment from the global West without any degradation in quality, which undoubtedly has facilitated a proliferation of Western content throughout much of the country's urban areas.

These connections also make it all the easier for Kenyans to stay digitally connected with one another as well.

I did not investigate internet's access upon attitudes about gender norms in Kenya during this study, but given that my participants are all engaged with Kenya's technology sector, it would be surprising if most of them were not accessing media from outside the country. As I briefly discuss below about the importance of social media, most Kenyan engaged with the tech sector make use of these platforms to stay connected and mobilize in times of mutual need.

Locations and Data Collection Methods

This study relies primarily upon participant observations and semi-structured interviews from the data collection phase of my dissertation, conducted in both Nairobi and Kenya from June 2021 to June 2022. In addition to the data collected during this phase, this study also includes observations made during two short stays in Kenya, completed in 2017 and 2018, in both cities. During my year-long residence, I maintained apartments in both cities and commuted between the two every two to four weeks, to cultivate and maintain relationships with communities in both locations concurrently. In Kisumu I spent my time at LakeHub, a tech innovation center, assisting with an introductory web development course offered exclusively for women. At the time of data collection LakeHub was located in the Milimani neighborhood of Kisumu, Kenya's then-third most populous city. This neighborhood is wealthier than others in the city and is characterized by a much lower population density, with single-family homes comprising the majority of its structures. LakeHub has moved around the city; during my first two visits to the tech innovation hub, in 2017 and 2018, it was on the northwestern edge of this neighborhood in a commercially-oriented property situated along a private road that stretched

between Achieng' Oneko Road and Lolwe Drive. This location was closer to the Kenyan president's official State House, the office's residence in the city.

By the time I moved into my apartment in Milimani in 2021 to begin data collection, LakeHub had moved to the center of the neighborhood along Okore Road, into what had previously been a single-family home. The organization built additional structures on the property for hosting company events, but their primary offices occupied about two thirds of the original, rectangular home on the property; they were subleasing the remaining portion of the home, as well as an additional structure - formerly used as support staff quarters for previous residents - to Kijenzi, a commercial 3D printing and manufacturing company. The original home is northeast-facing, set about 50 feet from the property's front fence (the entire property was surrounded by an approximately-12 foot concrete fence topped with razor wire), and the former staff quarters are set back from the southwest wall of the home by about 20 feet.

One additional structure, built onto the original home and extending back from its southern corner, is a large multi-purpose room. During my stay it was primarily set up with long desks and chairs as a classroom, arranged in a long "U" pattern to facilitate collaborative discussion. There was a large TV flat-panel at the end of the room with the open part of the desk setup, to which the class instructor could project their laptop's screen, for instructional purposes. At the opposite end of the room, behind the "U" desk setup, was a single row of desks and chairs, for additional student seating (and for any observers, such as myself) The room had multiple electrical outlets, from which LakeHub staff ran many power strips, so that as many as 25 or 30 laptops could be operated while being plugged in.

My Kisumu residence was just a short walk away from LakeHub: almost due west as a straight shot from LakeHub's gate (down to the southeast end of Okore Road, then a left turn

onto Busia Road), at a place called Kogelo Retreat Villas and Homes. Milimani neighborhood has also become the desired place for United States governmental institutions to locate their regional or national offices. While I was conducting data collection the United States Peace Corps had opened their Kenya office in the neighborhood, at first at a temporary location while they converted yet another single-family residence into their now-main headquarters for their Kenya program. The United States' Center for Disease Control, the United States Army's Walter Reed Medical Center, and the United States Agency for International Development (USAID) all also maintain offices and employee residences in Milimani.

When in Nairobi, I was attached to the Internet of Things (IoT) technology research team in iLab, which is an information and communication technologies (ICT) research and development center at Strathmore University. The university resides on a campus in Nairobi West, which is a southern neighborhood of the city that also houses Wilson Airport (the smaller of the city's two airports and a base for many of Kenya's regional airlines). The campus is tightly controlled, with main entrances found along a road that is blocked on either end with heavily reinforced and counterweighted boom barriers alongside large bollards. Taxis and other public service vehicles (PSVs) are generally disallowed from entering this street.

This road runs east-west through the campus, with high walls restricting movement through select gates, where security guards search bags, check IDs, and confirm one's presence as authorized. I spent the nearly all my time in the southern part of campus, which houses the Student Centre building in which iLab is located. Within the walls, the campus grounds are kept exceptionally clean and with properly maintained grass fields (which is uncommon in most of the country). The Student Centre is quite large, given how open it is on the inside. The ground floor contains the main cafeteria for this part of campus, as well as a small bookstore and

souvenir shop. The building is open in the middle, with an escalator running between the ground and first floors in this middle section, then with open air six stories up to the roof. Off to the south side of the building there is an alcove with a stairwell and an elevator that runs all the way up to the sixth floor. There is a smaller portion of the building, the eastern side of it, that is separated from this large, 5-floor open area; iLab is housed on the fifth and sixth floors of this section. The research center's physical space is a collection of classrooms, computer labs, open-plan seating spaces with dedicated electrical outlets, and a high-ceilinged event space for hosting public talks.

In each location – iLab in Nairobi and LakeHub in Kisumu – I spent roughly the first three months in participant observation, to orient myself within each community and cultivate closer working relationships with at least ten individuals. I would then rely on the ten for both initial interviews and anchors in my snowball sampling method. Interview lengths varied from under 20 minutes at the shortest, to longer than 90 minutes, though most were between 40 and 65 minutes long. Save for two exceptions, I conducted all the interviews on the premises of the organization where I was embedded: the LakeHub compound in Kisumu and the iLab offices in Nairobi. For one exception, I interviewed a company founder at their headquarters near Strathmore's campus; for the other, I interviewed a freelancer in his home office in another part of Nairobi. In total I interviewed 29 and 24 individuals in Kisumu and Nairobi, respectively.

Positionality

My connection to Kenya began with my Peace Corps Volunteer service there from 2010 to 2012, during which time I learned to speak Maa, the primary language of Maasai, as well as a smattering of phrases in Swahili. Upon returning to the US, I began learning Swahili in earnest as a part of my graduate studies. From 2012 to 2019 I made numerous trips to Kenya – and one

to Tanzania – during which I improved my speaking abilities in Swahili immensely. In addition to learning Swahili (and Maa) over those full 10 years, I also developed a strong knowledge of the Kenyan English dialect and accent. By 2021, when I moved to Kenya to conduct data collection, my conversational Swahili and Kenyan English were strong enough to serve me well as a part of my larger overall integration into the technology sector spaces that I was targeting. My ability to speak Maa in addition to these solidified my reputation as someone whose connection to Kenya was considerably deeper than other typical Westerners who might visit the country more frequently than mere tourists, but who rarely stay for very long. I balanced my participant observations and semi-structured interviews at iLab and LakeHub with visits to the homes of families with whom I have grown close throughout my previous time in Kenya, the large majority of whom come from Kenya's economic middle class, with only few family members in any of them connected to Kenya's tech sector. All these observations provided me with a broad picture of how those in Kenya's tech sector fit within the the country's middle class overall, as well as insight in to Kenyan middle-class attitudes about gender.

To be clear, I am a white, American, cis, straight man, with a greying beard, and was in my mid-30s at the time of my one-year residence. My appearance marked me as an outsider the moment any Kenyan could see me, though it is also true that several who met me in person only after speaking to me on the phone have remarked to me their surprise at this fact. The facts of my appearance are important caveats for me to remember while I am interacting with even my closest friends while in public, as my presence frequently changes the character of interactions with others in such situations. I take this reality to heart and have let it motivate me to spend considerable effort at speaking with, and behaving around, others while in eastern Africa in a way that is most comfortable, accessible, and intelligible as possible.

Background: Construction of Gender in Kenya

Current Kenyan conceptualizations of gender trace to the country's colonial past, during which British colonizing authorities sought to shift specific aspects of gendered customs, norms, and behaviors, as a part of their codification of so-called *tribal*[2] customs in service of the colonial project in the region (G. N. Kitching 1980; Lonsdale 1992c; Hodgson 2001). Even prior to colonization, most communities adhered to and reinforced a gendered division of labor (G. N. Kitching 1980; Hodgson 2001). As colonial authorities increased their extractive pressures on communities under their rule, these authorities implemented strict regulations that drastically intensified gendered labor divisions and reshaped their boundaries, such that men would become the primary purveyors of any activities that authorities understood to be economic in nature, which significantly worsened the lives and livelihoods of women (G. N. Kitching 1980; Lovett 1989; Mbilinyi 1989). Note that oppression via the facet of gender operated hand-in-hand with oppression via the facet of ethnicity (referred to as tribes). Colonizers relied on each facet to reinforce the other.

In places where agricultural production was reasonably viable prior to colonization, women and men both handled different tasks related to the cultivation of all the family's crops, but after colonial occupation it became expected that women were responsible for cultivating the crops upon which families subsisted and men were to grow, harvest, and bring sharecrops to pre-approved markets for sale as their sole owners (Lonsdale 1992b; 1992c). For pre-colonization pastoralists or others who kept livestock, both men and women had overlapping duties related to

[2] It is beyond the scope of this article to cover the complexities of the word *tribe* in the context of Kenya and its colonial history, but suffice it to say, this term essentially traces to the British policy of "indirect rule" over Kenya's diverse communities (Mafeje 1971). British colonization effectively created *tribes* out of existing ethnicities, including by grouping disparate communities who were not conceived of by themselves as unified as a single, monolithic group, thus creating a newly-named *tribe* (Mafeje 1971). Today, what Kenyans call *tribes* are better understood as ethnicities (Lonsdale 1992c; Lynch 2006; Hornsby 2012).

the tending of livestock and extracting secondary products, as well as engaging in inter-familial or inter-community livestock trade (G. N. Kitching 1980; Rodney 2012). During occupation however women were suddenly solely responsible for extracting secondary products like milk and blood from family herds, while men owned the animals in the eyes of authorities, so they were the only ones who were authorized to move them about for grazing, or buy and sell the animals at markets (Hodgson 2001). These conditions, at the endpoint of British occupation in December of 1963, meant that there was a significant gender disparity in Kenya with respect to ownership, agency, and economic activities available to men compared to women.

During the post-colonization period, from 1964 to today, Kenyan conceptualizations regarding gender norms have in many ways remained stubbornly resistant to change, despite consistent and overlapping attempts by governmental, nongovernmental, and international agency attempts to improve specifically women's lives in the country (Ochwada 1997). During the earlier decades of this ongoing period, there were concerted efforts by women's rights organizations to reduce the gender disparity in the country particularly with respect to access to economic activities (Ouko 1985; Toulis 1990). However, progress on this front remained difficult well into the 1990s and early 2000s (Cubbins 1991; Onsongo 2007).

Background: Kenya's Tech Sector

Within the context of Kenya's technology sector, the concept of gender and its shifting conceptualizations are impacted by tech development projects of governmental and nongovernmental international development projects, for-profit technology innovation initiatives, and online collectives of Kenyan women – whether feminist or not – such as the one which began the #MyDressMyChoice movement on Facebook in 2014, in response to a shocking incident of gender-based violence to be discussed below. The focus upon women in tech was

evident at the beginning of the 2010s, when I observed tech literacy projects specifically for women promoted by the Peace Corps during my service. In fact, the rise of Kenya's tech sector in the late-2000s was directly fueled by the lack of banking opportunities for the country's poorer inhabitants, and Kenyan ingenuity as a response to the brutal political and ethnic violence following the 2007 presidential election.

In 2007 the Kenyan mobile phone company Safaricom launched M-PESA, their mobile money service, to expand financial services to Kenya's poorer populations, who were unable to access the country's established banking institutions whether due to geography, illiteracy, or a lack of existing funds substantial enough to qualify for accounts (Marchant 2015; Eijkman, Kendall, and Mas 2010). When it launched, M-PESA occupied a role few other institutions could: the microfinancier (Eijkman, Kendall, and Mas 2010, 227). The new platform was an instantaneous hit, with its adoption by Kenyan households reaching the 70% threshold by the end of 2009 (Eijkman, Kendall, and Mas 2010, 221). By the time of my arrival in 2021, all major mobile phone networks in Kenya offered mobile banking of some kind; that same year 84% of Kenyan households were using these banking options (te Velde 2024, 22).

Kenya's other major tech sector success was created in roughly eight days, spanning the last few of 2007 and the first few of 2008 (Knowledge at Wharton 2013). Okune and Mutuku open with a brief description of the political and ethnic violence that followed Kenya's national election on December 27, 2007, and notes the lack of news or media coverage at the time (Okune and Mutuku 2023, 81). The silence prompted a collective of technologists, both in the country and abroad, to quickly produce *Ushahidi* (this name translating from Swahili as "testimony"), a phone and web application for crowdsourcing news and locations of violence (Marchant 2015). *Ushahidi*'s prototype was launched in the early days of January 2008 and was widely adopted for

other cases violence, as well as natural disasters, around the world (Knowledge at Wharton 2013). By 2010, *Ushahidi* had already been deployed as the technological foundation of HarassMap in Egypt, to track sexual harassment and violence in that country (Neylon 2017).

These two successes are products that directly improve the lives of Kenyans, both initially targeted to populations who were the subject of marginalization in one way or another. Just as importantly, these successes also quickly established the tech sector as key to Kenya's short- and middle-term development, as in 2008 President Mwai Kibaki announced a part of the Vision 2030 development plan to include building up the small community of Konza in Machakos County into a literal "Silicon Savannah,"[3] a tech-centric metropolis (Van Noorloos, Avianto, and Opiyo 2018).

By 2012, Kenya's rate of increase in internet access for its citizens outstripped nearly every other country on the African continent, save for South Africa. As cited above, by mid-2017 Kenya had more than 30 million internet subscriptions, driven primarily by the extraordinarily high cell phone penetration rate of 88% (Nyabola 2018, 36). Emblematic of this significant level of internet access, Kenyans online found themselves in a community they called "Kenyans on Twitter," using the hashtag #KOT[4] on that website to maintain their connection (Nyabola 2018, 89). The online community often took on political subjects with international connections and even occasionally successfully pushed back against "Western stereotypes" as presented in media (Machirori 2024, 137).

[3] Throughout the 2010s the moniker "Silicon Savannah," modeled after the US's Silicon Valley and incorporating the exoticism of an African savannah, saw widespread use outside of Kenya and, at least among my Kenyan friends and colleagues, considerable resistance. However, delving into this moniker and its usage (and rejection) would be beyond the scope of this study.

[4] The online events discussed in this article occurred when the website currently called X was under prior, public ownership (Just 2025, 41). At that time the website was called Twitter and the Kenyan-driven hashtag #KOT is an acronym containing this name. I therefore use this name here.

#KOT is no-less active with respect to important local Kenyan politics. Nyabola (2018) recounts a particularly salient example to Sonya's quote opening this article, highlighting the connection between gender norms and internet access. This came from a hashtag-originating movement, #MyDressMyChoice, which started on Facebook in November 2014 but quickly spread to other social media sites, including Twitter (2018, 130). The movement began as a direct reaction to a horrific sex crime perpetrated against a street vendor, part of which was filmed by bystanders and released online (2018, 128–9). #MyDressMyChoice sought to confront specific gender norms about women's dress in public, in an act of struggle against the common notion that men were entitled to determine what women should be allowed to wear while in public (2018, 129). Significantly, this online-first movement spread offline, sparking a large protest in Nairobi in support of the assault victim and as a means of social pressure upon the government to bring the perpetrators to justice (2018, 130). It also sparked a widespread debate among online and offline Kenyans about social mores regarding decency, women's dress, and respect for others (2018, 131, 137). The online movement brought about concrete offline results when the perpetrators were arrested before the end of that November (2018, 130). Not only were the suspects convicted and sentenced to death (BBC News 2017), but the protest pushed Kenya's government to adopt new criminal laws against the "stripping" of others and mandated harsh prison sentences (Institute for Transportation and Development Policy 2018).

At the time of our interview in 2022, Sonya was a 21-year old Information technology (IT) student at the Kisumu branch of KCA University (originally titled, "Kenya College of Accountancy"). We met in the aforementioned web programming classroom at LakeHub. Sonya's comments about her choice in attire came a full seven years after the #MyDressMyChoice protest. Additionally, it is difficult to imagine how her clothing decisions

would have been criticized by someone concerned about decency within the context of sexualization as her outfits were routinely composed of loose-fitting t-shirts and relaxed fit jeans or other types of pants, rather than the more tight-fitting styles that had since become commonplace among women in Kenya's larger urban centers like Kisumu. Even still, Sonya's reflection upon her attire decisions reflects the significant shift in gender norms in the country. Rather than being someone left out of the web development course's social circles, Sonya was personable, outgoing, and easily established and maintained friendly relationships with a majority of the other women from the course's outset. If her attire had a negative impact upon other women's perceptions of her as a young Kenyan woman, to me that impact appeared small and ultimately unimportant in the larger scheme of things.

Interview Responses

When conducting interviews, I began nearly every one with some variation of the same prompt: "tell me about yourself, the things that, the people who know you, they know about you." Then, because I was recording each interview, I added "but not your names," to try and add an additional bit of confidentiality. This pushed my participants to consider themselves beyond an initial, 'here is how I introduce myself to a stranger' and consider what they think is of importance to their identity. 52 of 53 participants did not specifically state their gender; this is of no surprise because, when speaking with someone in Kenya, assuming their gender is an expected behavior (I will discuss the one outlier to this below). Common responses included people's current educational status, recent educational history, hobbies, professional interests, descriptions of their sociability (such as whether or not they enjoy parties), and where they were born or grew up. Coral's response was an amusing outlier, as she took the opportunity to bemoan the question with a generalization about Kenyans: "why is it that every time you're asked to talk

about yourself, us [Kenyans] we are like, 'aarrgh?' [Laughs]." My experience has been quite different to this generalization.

Regarding gendered responses to this initial prompt, the most significant discrepancy was that no men but three women stated their familial status, such as being a wife, or being a mother and stating the number of children they had. Importantly, I would ask after these very traits later on in an interview, should they not have come up prior, so I can confirm that at least 15 participants had children, were married, or both. The women who provided this information as a part of their response to my initial prompt illuminated an interesting potential gender norm, that professional women are much more likely to hold familial traits as important to their identity. This could however be explained by the comparatively low number of people who participated, as I interviewed 32 women and 21 men. Another four women and two men spoke about other familial traits, such as the number of siblings they have, or who raised them through childhood.

Laura was the one outlier, in having provided her gender in her introductory response, along with another aspect of identity that no one else provided. Halfway through her response to my opening question, she shared with me that she was gay and followed that with, "my pronouns are she her." This decision of hers was certainly a risk – homosexuality is criminalized in Kenya – but Laura explained after our interview that my demeanor during the first few months of our interactions in the class had conveyed to her that I was someone to whom it would be safe to provide this information. She also wanted to explain that, though her sexuality is criminalized, there are small bits of progress in the country, including regarding her and other LGBTQ individual's ability to seek out help when needed, telling me, "The gender desk at the police station, they have started considering that there is [an LGBTQ] community that exists, so they put open-minded police officers at the gender station." But she clarified, saying that although

others of the community feel comfortable going there for help, she still does not. “Gay people get killed, transgender people get killed,” she tells me, reiterating the reality for her community in her country.

When visiting with my close friends and colleagues over the years, discussions about LGBTQ communities would occasionally arise and during these conversations it was clear that my friends’ perceptions of Kenyan attitudes, whether they agreed with them or not, were decidedly negative toward anyone who was not straight and cisgender. Among even those who professed their acceptance of members of these communities, many still expressed certain reservations, such as an unwillingness to allow their children to watch tv shows or films portraying same-sex relationships or transgender characters. These reservations extended to other types of content as well, including particularly passionate kissing or scenes that heavily imply sexual activity between characters. But hand-holding, cuddling, or minor kissing among straight characters would be acceptable, where any of these behaviors among gay characters were unacceptable.

Taking Kenyan attitudes regarding LGBTQ communities into account, Sonya’s experience with another student’s perceptions of her clothing were perhaps, or likely, more about whether Sonya was dressing feminine enough. When responding to my opening prompt, she ended by saying, “I like technology, anything technology. Like, if you were inside my room, you’d think it’s a boy’s room. I have speakers, I have old tv screens, I have… like, how many laptops there am I trying to fix?” When asked to clarify why her room was like a boy’s room, she responded, “well compared to my friends… like, if you compare it to my friends’ [rooms] and maybe my niece’s room, it’s so different. I don’t have pink things. Most of them [her things] are like blue and purple. Yeah, I don’t have high heels. I don’t have skirts.” Renèe, an intern

working on one of iLab's teams, shared a story about clothing that similarly hints at societal concerns about women wearing apparently-masculine clothing. She spoke of a common occurrence at the university's security checkpoint, saying "I get issues at the gate at the entrance. So [the guards] would say my clothes are not appropriate for Strathmore, but there are other people, who are slimmer than I am who wear something tight and they will be allowed." When I asked what it was about her clothes specifically that the guards would take issue with, she responded, "Its trousers, not even tight trousers." Her experience aligns with cultural training my Peace Corps group received when we initially arrived in 2010, when women were told they should not be wearing pants at all in their rural communities, and should strongly consider not wearing pants when in cities, because such clothing was at that time considered inappropriate. Strathmore University, being an Opus Dei oriented institution, expects its students, employees, and visitors to adhere to a dress code, of which I was made aware when I arrived. For men, this meant wearing full-length pants that are not jeans, close-toed shoes, shirts with collars covering the shoulder and at least the upper part of the arm, and no hats (though I was allowed an exception, because of, as one guard put it, my "complexion"). It would not surprise me at all that women were held to similarly-strict and conservative standards.

Sonya's interview was bookended by specifically her clothing choices, with respect to whether or not she was presenting as feminine enough compared to other girls and women around her. Her introduction of herself included what she viewed as masculine-oriented visual tastes and hobbies. It is quite likely her comments were an acknowledgement of the distance between how she presented herself and the gender norms expected of a 21-year old single woman. Additionally, she framed her interest in technology as a distinctly-masculine trait as well, which was one response among many to indicate that Kenyans consider technology and the

tech sector to be more appropriate for men than women. My observations at iLab, LakeHub, and with Kenyan families, as well as responses during my interview, show that the association between masculinity and technology is still present in Kenyan society, though many also indicated their personal disagreement with this belief.

The large majority of those I interviewed shared about significant gender imbalances and discrimination in their computer science or information technology coursework or tech sector workplaces, with men outnumbering women by significant margins. When asked, many responses illuminated socially-ingrained gender norms. For instance, Chandler, a data scientist at iLab in Nairobi shared, "as a female you would be kind of pushed towards social sciences… Ok fine, naturally apparently women tend to focus more on people than on things, while men want to focus more on things than people, in general." The historicity of this sentiment was also shared by Scofield, a computer programmer and instructor at LakeHub. He shared, "these [computer] engineering courses were for men, and the social courses were for women." He went on to note that places like LakeHub were directly addressing the gender imbalance in the tech sector: "part of why we have [women-only] boot camps, is try to address those imbalances." When asked why the imbalance persists, Scofield added, "women are our homemakers and males are the ones actually going outside to do those hard factory jobs. So now it's like women are coming out of that homemaking environment, to [work] in tandem with the male folks."

Selena, who worked in a communications role at LakeHub, spoke about direct discrimination she experienced as a tall, attractive woman in the workforce, stating, "when I ended up in hospitality, people would say, 'it suits you, it suits your beauty, it suits your face, you look like you know you're the face of the hotel.' So there are always those comments, but when [they stare], they say 'just because you're a woman and you're beautiful, then this career

suits you, because of your beauty and nothing more.' I always have to prove [myself]. I want to prove to people and do more to prove what beyond my physical appearance. I have brains!" One of the project managers for a team in iLab relayed a story about how, before she was hired for her current position, she had been working in a finance position elsewhere, but the institution had labeled her job redundant and she was laid off. They then immediately turned around and hired a man for substantially the same position. "I was getting paid 80 [thousand shillings per month], he is getting paid 200 [thousand shillings], for the same job. And then they gave him the title 'Finance Manager,' but he's doing the same job. In fact, he's doing less, because some of the tasks I had were then passed to other in the department."

Danny, a project manager for one of the tech development teams at iLab, shared her perspective as to why she sees a gender imbalance on the center's Internet of Things (IoT) team: "I have been told, women are scared of IoT. There are some who are interested, but when you get into the details–that I never do–the detailed hardware guys[5] run away." To follow this up though, Danny observed an increase of women in the tech sector overall, saying "by the way we never used to have so many women in IT; now we do. It's like it's that career path that we never ventured into that much, but now we do. Maybe it's the imagination: that [before], women can't do this, and now women can." When I noted the low number of women in IoT to Kadzo, another project manager for a separate tech development team, she wanted to qualify this fact a bit: "IoT has the least women, but the [iLab] research center is trying to promote women. More often, most of the women [working in iLab] are the ones that are leading teams. So, you'll find most of them are the managers." Kadzo was misspeaking slightly, as I later clarified with her that what

[5] "Guys" here is in reference to women. I frequently witness this usage of "guys" in Kenya, including among all-women groups who are addressing each other as a whole.

she meant was, most of the teams were led by women, not that most of the women were team leads. When asked to clarify, she shared that there were still more men than women working in the different teams, though being much closer to parity than the single woman (at that moment) working on IoT and the two–including herself–on her own team. She added that her own team had been much closer to parity in the recent past, but a number of departures, leaving open positions, had at that moment changed the gender proportions. Of the five research teams in iLab, the only one with a man working as the project manager was Data Science.

It is possible, if not likely, that iLab made a concerted effort to recruit and retain a diverse workforce, which explains the comparatively larger number of women, with women in positions of authority, in their ranks. Students who I interviewed nearly universally described a stark gender imbalance in their computer science cohorts at their university. Josephine, who I met in the web programming class at LakeHub, told me she is currently perusing her computer technology degree at Multimedia University, just outside Nairobi; in her program there are only five women, of 73 total students at the same grade level. I would say it is likely the two main spaces I was able to observe for data collection – iLab and LakeHub – are not typical of the largest tech sector employers in Keyna, such as Safaricom or Jumia (an e-commerce platform).

It is certainly the perception within both of the spaces I operated that women are underrepresented in Kenya's tech sector; another student at LakeHub, Maureen, shared that she had just attended a seminar the week prior to our interview given by a woman who worked as a product lead at Safaricom, who had told the attendees that Safaricom's tech employees were roughly 20% women. Coral, a senior administrator within LakeHub's executive staff, expounded upon the organization's goals in improving women's representation in Kenya's tech sector, telling me, "we are bringing in more women as students. But we also have to be very deliberate

in how we conduct our trainings and design our programs, so they include the curriculum in a way that will suit women. We want to make sure they are comfortable and can get to their potential." Though most of those I spoke with in observations or interviews expressed the view that the stereotype of women being ill-suited for work in the tech sector was not at all accurate or appropriate, it is obvious there are still significant barriers to women even pursuing this as a career at the same rates as men, which may impact their ability to find employment once finishing their training. Yet many women I interviewed shared their resolve to push forward, succeed in the industry, and bring about this change. For instance, Rose from the LakeHub web programming class said, "if it's something you want to do, your passion, you go for it, even if you are one person in a class of forty boys… I don't know, I see people motivational speakers who they say, 'if you are a lady, you have like to work twice as much for you to get opportunities.' I somehow agree."

Caveats and Future Research Opportunities

As I noted above, there was another trait that was universally absent from my participants' introductory descriptions of themselves. This was anything directly related to their *tribe* or ethnicity. This however is to be expected, given Kenya's history of ethnic tensions, particularly those with roots in the period of colonization. As long as I have been visiting Kenya, I have observed that it is offensive to refer to people simply by their ethnicity, especially once someone knows a person's name, which should be used instead. I have observed that it is offensive to initially introduce oneself as being a member of a particular ethnicity. And I have observed that it is offensive to outright ask a stranger or distant acquaintance one's ethnicity, a mistake I made early on but which I quickly learned to avoid.

For this study, I did ask participants which languages both they and their parents spoke, in order to make confident assumptions about each participant's ethnicity. Most participants readily provided this information to me, despite each likely knowing exactly what I was attempting to learn, but it seemed to me that either this method of asking after ethnicity was culturally acceptable, or my status as fundamentally an outsider, no matter how well I maintained a 'Kenyan' accent and demeanor, combined with the effort I put in to integrate myself into these two communities, afforded me the cultural capital required to break social mores and ask about this subject. Though I would be somewhat confident in my assumptions of the ethnicities of all but five of my interview participants, ultimately the small sample size made this information less helpful with respect to the gender norms I discuss here.

Another facet of identity which is unacceptable to request is sexuality, which is unsurprising given the attitudes about the subject I shared above. Kenya has a small but significant LGBTQ community, to which Laura was all but willing to testify, but it was not possible for me to determine with any kind of certainty the sexualities of anyone – straight, gay, or otherwise – who did not freely and readily provide it. Additionally, and unlike ethnicity, I struggle to think of any tangential indicators about which to ask, in order to make any kind of confident assumption without also putting myself in danger or increasing the overall danger of LGBTQ community members around me.

There was however one facet of identity that was exceedingly easy to ask of people, their religious affiliations, with every participant providing this information readily. According to Kenya's 2019 census, more than 85% of the country's population believes in Christianity, with another roughly 11% being Muslim (Kenya National Bureau of Statistics 2019, IV:422). No one seemed hesitant to discuss their religious affiliation with me – to the contrary, universally,

everyone seemed pleased that I was asking – including the four participants who told me they are not religious. Once again though, the small sample size of my participants rendered this information unhelpful when evaluating interview responses.

Finally, asking after age was trivially easy, though as with the others, its use in this study was limited.

In future research investigating gender norms, or even attitudes on other important social issues, it would be quite useful to take a mixed methods approach to data collection, to better collect a robust amount of data from varying perspectives about these subjects. Having the opportunity to consider not merely one's gender or age, but their ethnicity, religious affiliations, and sexuality as well, would be enormously beneficial to taking an intersectional approach to the subject, as a means of producing a much more deeply-contextualized understanding of the attitudes encountered.

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CONCLUSION

There are three purposes of this dissertation. The first is to explore Kenyan identities and their impact on beliefs and attitudes about gender within the country's technology sector. Second, *intersectionality* has important potential for future research into Kenya's tech sector when the concept is deployed during study design and data collection and analysis. *Intersectionality* especially is crucial to how research into the tech sector can progress itself as a part of an intersectional feminist project, which takes seriously the pursuit of all facets of identity-derived oppression, rather than paying some attention to non-gendered oppressions only when doing so serves to benefit partial progress in reducing oppression of women in Kenya's tech sector. These oppressions are found in sector research in the form of exclusions; working to reduce these exclusions will only serve to progress the project toward a less-oppressed reality. And finally, there is a specific methodological lesson, which arises from the three manuscripts contained herein: that *communities of practice* are not only theoretically-conceived by researchers, but instead can be both constructed and shaped by the community members themselves. And

This dissertation project was originally conceived as taking an intersectional approach to identity in the tech sector for teasing out potentially unseen biases about who studies for or works in the sector, or how overlapping identities might affect the beliefs or attitudes held about different genders. It was to rely on a mixed-methods approach to data collection, via a questionnaire to be distributed to university IT students in classrooms, to gather a larger set of demographic data and allow for interview solicitations to more closely match those demographics. Additionally, the study was also designed to include focus group discussions, to allow for joint conversations.

COVID-19

The data collection phase of my dissertation was set to begin by the end of March 2020, but one week prior to my departure date, Michigan State University (MSU) suspended all international travel. Without MSU's approval, the US Department of Education (US Dept. of Ed.)–the federal department that awards Fulbright-Hays Doctoral Dissertation Research Abroad grants like mine–also would not approve travel and required a repayment of all the startup funds that had been disbursed to me just prior to my intended departure date.

As the uncertainty of the pandemic's end drew on, I was fortunate enough to secure a position with the Active LENS research team here at MSU's BEACON Center for the Study of Evolution in Action, to design and lead the implementation of a qualitative research project, then produce a manuscript for publication with co-authors from the team. This publication is the first manuscript herein. This began with my observation of the 2020 Active LENS virtual workshop, where I actively participated alongside the invited cohort in order to learn about Avida-ED and how to utilize it in a classroom setting. Though not specifically a method of data collection for the eventual study, the two and a half days of participant observation did provide me with insight into the practice community under construction in these workshops (see Methodological Lesson, below). The design and data collection phases of this project were completed after this virtual workshop, but before the end of 2020; at the time of my onboarding, the earliest estimated departure date from the US Dept. of Ed. for those traveling to Kenya was January 2021. I used the opportunity of this study to both test my semi-structured interviewing skills and gauge the feasibility of redesigning my dissertation project to only collect data via videoconferences. Though this study was successful and I gained valuable experience in semi-structured interviewing, the technological barriers present for those with whom we were videoconferencing

who universally all had reliable electricity, internet, and personal computers, I realized these barriers would lead to significant gaps in potential virtual-only participants from Kenya, particularly among those with fewer economic resources at their disposal. However, the methodological overlap between this virtual study and the later one I undertook in Kenya should not be overlooked, as particularly my experiences in participant observation just prior to the study design, as well as drafting and iterating a semi-structured interview protocol and undertaking qualitative data coding and analyses.

After several more months of delays, MSU implemented a waiver process for PhD candidates to request international travel approval for dissertation research. During this waiver process I adjusted my data collection activities to limit the potential for the spread of coronavirus by eliminating the university student surveys and focus groups, and added the distribution of face masks for any one-on-one interviews. Following MSU's approval, the US Dept. of Ed. approved of my travel as well and released my grant funding.

Intersectionality, Research, and Intersectional Feminism

The adjustments to my dissertation's data collection methods resulted in much less data for analysis and impacted my attempt to control the demographic makeup of my participant cohort in "Gender Norms." These changes limited my analytical flexibility for working with the data I did collect, which ultimately led me to put aside the concept of *intersectionality* for the study. To counteract this, I included the second manuscript herein, the World Bank Gender Innovation Lab (GIL) internal report, "Qualitative Data Collection Report: Educational Training Opportunities in Kenya's Technology Sector" and wrote for it a brief forward presenting the conceptual content of our conversations during this study's initial design phase. By including in

this project *intersectionality* as an analytical frame, the data collected ended up revealing some interesting details about our participant cohort.

The report notes the overrepresentation of certain ethnicities and underrepresentation of others when compared to demographic statistics from a Kenyan government census. It also notes that, for religious affiliations, most of those who identified as Catholic were men (seven of nine participants) whereas most of those who identified as Protestant were women (11 of 14 participants). However, what I missed at that time were two apparent imbalances: one with ethnicity cross-referenced with gender for the entire cohort, and the other with religious affiliation cross-referenced with gender for the entire cohort. The large majority of men we interviewed identified as Kikuyu (eight of 11 men), whereas the ethnicities of women interviewed were spread over several ethnicities with the plurality identified as Luo (11 of 25 women). For religious affiliations, most of those who identified as Catholics were men (again, seven of nine), but also, most men identified as Catholic (seven of 11 men). For women, the discrepancy is even more stark: most of those who identified as Protestant were women (again, 11 of 14), but among all women, Protestant was the stated identity of only a plurality at 11, with the "unknown" category for Christian identity sitting at 10.

Most men in the cohort are Catholic and most Catholics in the cohort are men, but the data for religious affiliations of women is more ambiguous. Similarly, most men by far identified as Kikuyu, but the ethnicities of women were spread out with no one ethnicity holding a majority. Are these outcomes related, such that Catholic men are more likely to be Kikuyu and Luo women are more likely to be Protestant? Or is there another facet of identity at play that impacts both religious affiliation and ethnicity in some unknown way? These discrepancies,

identifiable only by incorporating an intersectional aspect to the study's design, are worthy of further exploration as a means of answering these lingering questions.

I argue that the incorporation of an intersectional approach to study design and data collection and analysis would greatly improve this type of research into Kenya's tech sector as well as contribute to the broader movement of intersectional feminism for addressing all forms of oppression. This wider approach to alleviating oppressions that marginalized peoples face requires taking seriously the non-gendered oppressions at play, rather than merely paying service to them when doing so serves to partially alleviate oppression being faced by women, who would then remain centered.

The overlap of activist and scholarly pursuits among intersectional feminists is a key feature of the movement; Zaatari places special importance of the movement's "invest[ment] in producing knowledge)" (2022, 239). Naber and Zaatari underscore the importance of an intersectional approach to feminist activism and scholarship, through their analysis of the 2006 US-backed Israeli invasion of Lebanon, which brought about a crisis in which feminist activism was "limited [to]… limited feminist and LGBTQ work that focused primarily and solely on gender or sexuality," (2014, 97). This limitation brought to the foreground the profound importance of an "intersectional approach that refuses to impose false binaries or hierarchies on a complex social reality" in research as well as activism (Naber and Zaatari 2014, 92), later concluding:

> Our research participants' stories about the 2006 war in Lebanon show how concepts and practices of family, gender, and sexuality are shaped and impacted by various forms of structural violence including classism, sectarianism, racism, and militarism, and these same forms of structural violence were defined by concepts of family, gender, and sexuality. (2014, 96)

Others echo the importance of intersectionality in recent feminist scholarship, in situations much less urgent or dangerous as the war discussed in Naber and Zaatari (2014). Jolly directly states her vision for *intersectionality's* place in feminist scholarship, as "a practical prism that distils, reflects and refracts a complex reality" for engaging with the many contexts of the other contributors' pieces within the edited volume that her chapter appears (2021, 443). As a final example, Lukose contrasts the coinage of the term *intersectionality* by Crenshaw in the late 1980s and its focus on interesting power structures that impose identities on women, " more contemporary [to the late 2010s] mobilizations of the term focus more on the possession of identities that women bring to the feminist table" (2018, 39).

All these examples however center the identity *woman* in their presentation and analysis of intersectional feminism and the importance of this framework for addressing inequalities and inequities. My argument however is for a decentralized target of intersectional feminist activism and research, which takes seriously hooks' intersectional definition of feminism I quoted in the forward to Manuscript Two, which is as "a movement to end sexism, sexist exploitation, *and oppression*" (2015, viii; emphasis added). Intersectional feminism maintains the same goal as the feminist movements appearing before it – namely, to end oppressions of women by bringing about equitable conditions among all genders – however its approach for doing so casts a much wider and bolder net than those before by, as Levendowski points out, recognizing that "oppression comes from many sources and [intersectional feminism] provides a framework for addressing the oppression of people with overlapping identities… and *even oppressed people who are not women at all*… a broad approach is crucial to realizing that equity for women that fails to dismantle oppression broadly reflects a privileged and partial feminism" (2022, 804; emphasis added).

Though I am arguing to decenter *woman* as the focal identity for reducing oppression of women, I am *not* arguing that the goal of reducing oppression of women is no longer the goal of feminist activism and research. I am instead arguing that, as Levendowski (2022) frames it, addressing the oppression(s) of women will require taking seriously the intersectional feminist treatment of other identity aspects, because leaving any one of them standing as a route through which some oppression may occur will inevitably leave the door open to oppression returning to those identities, including and especially *woman*, which may have temporarily found relief.

To bring back the introductory explanation for *gender* and *tribe/ethnicity* as identity categories in Kenya, I would like to emphasize the intersectional way in which the two were purposely intertwined by colonial authorities via *tradition*, in service of Britain's policy of indirect rule over the region. Both *gender* and *tribe/ethnicity* were important identities to British oppression of Kenyans and the intertwining of the two made this oppression possible. I would argue, though in simplistic terms, that this oppression continues to this day, though it is no longer the British (or, at least, no longer solely the British) who maintain this system of oppression in the country and for this system to be dismantled, both will need to be taken down in order to do so. Until both are addressed, women will continue to face this oppression.

Methodological Lesson: Constructed *Communities of Practice*

Finally, there is a methodological lesson to draw from this dissertation is about how *community of practice* is not limited to application in circumstances in which the community is a theoretically-derived group. It does seem however that much scholarship about *community of practice* does concern itself with the potential benefits of a theoretical definition of the community. Bucholtz speaks about "defining the community" of practice for analysis, who are theoretically bound together via shared practices, even when "difference and conflict" among

members is "the ordinary state of affairs" (1999, 210). Vietti covers the benefits of theoretical community definition in situations of “conviviality” among members, “without defined and stable boundaries” (2024, 215). In doing so, Vietti (2024) notes that the community’s definition need not rely on a shared trait distinct from others, such as ethnicity or workplace.

However, others who have theorized about the *community of practice* framework have done so with an implicit assumption that the community is not merely theoretically defined by researchers, but instead is one of practitioners actively engaged with one another in ways which promote the sense of community, without the “difference and conflict” described by Bucholtz (qtd. above). This approach to the framework is found in contexts of development. For instance, Viartasiwi uses the framework to describe as a *community of practice* those in Indonesia who closely interact with one another as “civil society organization (CSO) activists,” or nonstate actors who serve as liaisons between state officials and refugee beneficiaries of development the state wishes to implement. In this context, the practice community is one engaged in facilitating development, yet excludes those who are seeking developmental outcomes (state officials) as well as those who are receiving the benefits (refugees) (2025, 238). In Bala and Dizolele (2025), this framework is taken a half-step further. In the case of Nigeria, Bala and Dizolele points out the unifying power of the *community of practice* framework, in which, local and international nongovernmental agency employees working on security policy as well as Nigerian security personnel could benefit from recognizing their mutual and intertwined work toward improving safety and security in the country (2025, 15).

Yet *communities of practice* can be constructed and shaped by practitioners themselves, whether unintentionally or with conscious intent. With the practice community from which participants were recruited for the "Teaching with Avida-ED" manuscript, this community was

specifically built by the Active LENS research team. Recall that Duguid notes how a community of practice is one in which members "learn to be" members of the community by "learning how" the community practices (2005, 113). This emphasis upon the learning process is what shows how practice communities may even be built out of members from otherwise-diverse backgrounds. This is the case with "Teaching with Avida-ED," where the workshops held over several years and at multiple locations, though varying through time, still sought for its attendees to learn how to be education practitioners who use Avida-ED to instruct students. This manuscript does not explicitly describe attendees as a practice community, yet the study's design and analyses implicitly hold that it is one.

The *community of practice* framework is similarly implicitly in play within Manuscript Three, "Gender Norms." Of particular interest are the the statements by Coral, which show how LakeHub is consciously attempting to shape the already-existing *community of practice* (obviously without calling it as such) in Kenya's tech sector by not only recruiting women to their introductory programming courses and instructing them on the technical basics required for careers in the sector, but designing course curricula in such a way as to enculturate women into the community via their own terms. Coral shares that this practice at LakeHub is "deliberate" (qtd. in Manuscript Three). Less directly, other participants from both Nairobi and Kisumu spoke about the need for change in the sector with respect to incorporating women, particularly in changing public perceptions about who it is who are suitable for tech sector work. Additionally, participants in Nairobi pointed out, though women among their ranks are fewer in number than men, more women hold the supervisory role of project manager, with Kadzo specifically stating that project managers are "leading teams" (qtd. in Manuscript Three). Statements like these speak to how participants are learning how to be members of the tech sector, their desires for

others to be given the opportunity to also learn how to be, and their acknowledgement of the strides women have already made in securing supervisory roles within the sector.

Conclusions

The three manuscripts in this dissertation together provide the components for potential future research into how identities impact beliefs and attitudes about gender in Kenya's tech sector. These components are well-suited to identity research in other contexts as well: the *community of practice* theoretical framework provides solid justification for containing diverse individuals within an analytical cohort; an intersectional approach to a mixed-methods data collection allows for more potential categories for future analysis; and intersectional analysis yields the opportunity to uncover surprising analytical connections that would be otherwise opaque during analysis. Of particular importance is that an intersectional approach to study design, data collection, and data analyses, will meaningfully contribute to not only a better understanding of Kenya's tech sector and its practitioners, but will additionally bolster the intersectional feminist movement in its pursuit of bringing an end to all oppressions in service of ending oppression of women.

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