Designing a course-based community consultancy: challenges and lessons around structuring a large class as a collaborative organization

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The rapid pace of technological innovation and its impact on the economy and on society has led to calls for higher education to prepare students with more real-world, experiential, and community-engaged learning that can equip students with the skills needed for transitioning into the workforce and for developing technologies for the public interest. Yet while many learning technologies have helped to scale content-based learning, it has been challenging to scale experiential, community-engaged courses due to the resource intensive nature of such instruction and the tension between the quality needed to deliver sustainable value to community partners and the reality of what's possible in time-constrained student projects. In this paper, we discuss the design of a course-based community consultancy, in which a large class is structured as a collaborative organization towards providing experiential apprenticeship-like learning dynamics to students at scale while also delivering sustainable value to community partners. We describe design iterations of a class with ∼120 students over a three-year period of time (once per year), present challenges encountered, lessons learned, and design patterns developed, and discuss opportunities for using ideas and technologies from crowdsourcing and CSCW to create organizational structures for large classes that can simultaneously meet the needs of student learning and community clients.

CCS Concepts: • **Human-centered computing → Computer supported cooperative work**; • **Social and professional topics → Computational science and engineering education**.

Additional Key Words and Phrases: experiential learning, community-engaged learning, crowdsourcing and collaboration

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1 INTRODUCTION

"In the past, we learned in order to work. Now we must work to continuously learn." -Heather McGowan

The rapid pace of technological innovation has led to a labor market undergoing continuous change, with as many as 60 million jobs turning over in the next two decades [57], and an increasingly sociotechnical society, with digital systems playing growing roles in contexts as wide ranging and fundamental as health, education, and civic engagement. These have led to calls for higher education to prepare students with more real-world, experiential, and community-engaged learning that can, in the former case, equip students with the skills needed for transitioning into the workforce [14], and in the latter case, equip students with the skills needed for developing technology for the public interest [66].

Unfortunately, doing so requires overcoming significant obstacles. First, experiential learning is resource intensive, often relying on apprenticeship-like dynamics [11] in which mentors provide personalized guidance and critique tailored to the needs of a given project. Second, experiential learning requires making hard trade-offs in project scope, with tight time constraints (such as 10-week quarters) preventing students from experiencing larger more real-world projects, from

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iteratively revising work towards higher-quality professional outcomes, or from spending sufficient time to understand user needs and define project requirements. These challenges are even more pronounced for community-engaged learning, where it is even more important that projects produce sufficient real-world value for community partners to justify the time they need to put into interacting with students. The end result is that such courses often highly restrict participation, while also stretching student teams to their limit, resulting in an experience that is fragile and stressful. Many restrictions based on prior experience can also disproportionately impact underrepresented students [52], creating barriers for accessing the experiential and purpose-filled learning that has been shown to increase motivation and retention for underrepresented populations in CS [23, 33].

To some degree, these challenges reflect the existing state of research on learning at scale. While there has been tremendous progress in supporting content-based learning, e.g. through MOOCs and related products that center on predefined lectures and assignments [78], scaling experiential and project-based learning — learning that requires studios, teamwork, mentorship and other forms of interpersonal support and interaction — remains elusive.

In this paper, we explore the possibility of designing a course-based community consultancy that structures a large class as a collaborative organization to provide experiential apprenticeship-like learning dynamics to students at scale while also delivering sustainable value to community partners. A growing literature in crowdsourcing and collaborative work has explored new ways to organize large numbers of people around complex collaborative projects and to link learning to crowdsourced collaborative efforts [40]. These make it possible to imagine new organizational structures that can enable new forms of experiential, community-engaged learning at scale.

To work towards this possibility, we took a design-based research approach [34, 63, 85] to making multiple design iterations of a class with ~120 students over a three-year period of time (once per year). We explored and reflected on concepts for providing scalable real-world community-engaged learning experiences for students of any background, paying particular attention to: 1) the challenge of organizing a large group of learners to deliver high-quality real-world outcomes, which we see as having implications for learnersourcing, collaboration, and learning at scale, and 2) the challenge of supporting alignment and relationship-building in university-community collaborations, which we see as having implications for digital civics. In the following sections, we review relevant literature on experiential learning, crowdsourcing, and collaboration (**Section 2**), describe our overall approach (**Section 3**), and reflect on the design iterations we made in our course (**Section 4**). We conclude by discuss broader implications and design directions (**Section 5**). Specifically, we show that large and diverse classes can be a strength rather than a weakness for experiential, community-engaged projects, demonstrate that the course-based community consultancy model can contribute to larger collective impact efforts, and present multiple ways in which the challenge of structuring learning after the workplace is full of opportunities for new design contributions.

2 RELATED WORK

2.1 Experiential learning and the challenge of scaling

To meet the challenge of a rapidly changing world, a large literature on educational technologies has sought to provide new forms of learning and upskilling, painting a vision of lifelong learning accessible to all [78]. However, while there has been tremendous progress on scaling content-based learning in contexts such as MOOCs [6, 7, 21, 35, 40, 42, 45], the literature on scaling experiential learning is limited. In the following, we review literature at the intersection of the learning sciences and social computing to paint a picture of how experiential learning works, the gap that remains to providing it at scale, and the advances in crowdsourcing and computationally-mediated work that suggest new opportunities for experiential teaching and learning.

2.1.1 Experiential education and related theories. Experiential education stems from Pragmatist philosophy that thought itself is rooted in "the exchange between an organism and its environment" [55]. It was carried into education by Dewey [16, 17], and led to a plethora of theories and pedagogies such as experiential, problem-based, constructionist, service, situated, and apprenticeship learning, all stressing direct experience [11, 31, 39, 46]. The theory of how individuals learn in such settings, i.e. experiential learning, has roots in Piaget's theory of constructivism, which states that individuals learn by constructing knowledge in their mind through reflection that helps them to build and evolve knowledge schemas [77]. Thus, experiential learning rests on two key requirements: opportunities for authentic real-world learning experiences and reflective incorporation of those experiences into schemas of ideal practice. As articulated in Kolb's experiential learning model [43], these happen in an iterative cycle in which concrete experiences lead to reflective observation, abstract conceptualization, and finally active experimentation. The goal is to help learners acquire tacit knowledge such as concrete 'know-how' or ingrained mental models that are hard to express, context specific, and rooted in individual experience [53, 56].

2.1.2 The Zone of Proximal Development and challenges for scaling. One challenging aspect of experiential learning is that one needs to obtain opportunities for authentic real-world learning that are within one's Zone of Proximal Development (ZPD) [76], the set of tasks that one is unable to carry out alone, but is able to carry out with support from a "more knowledgeable other". This is challenging because it is not only hard to find mentors with the necessary time and expertise, it can be hard to obtain opportunities at all due to the limited experience that learners have (by definition of being within their ZPD). Learners are often stuck in a vicious cycle where they need experience to gain experience, making it hard to reskill into new fields or transition from the university into the workforce.

2.1.3 Apprenticeship learning. A particularly effective but mentor-intensive approach for learning within one's ZPD is through apprenticeship learning in which an expert provides authentic work for the learner as well as mentorship, helping them to move from deep observation to skills acquisition to active experimentation [28] through methods like modeling, coaching, scaffolding, articulation, reflection, and exploration [12]. In scaffolding, mentors start learners off with a small scope of work (or with a low degree of independence) that is gradually increased over time, essentially creating pathways for experiential learning of complex skills. During this process, mentors model their own process and coach learners. Learners evolve knowledge schemas by articulating their process, reflecting on how it compares to that of mentors or peers, and exploring their evolving schemas in new tasks. These transition the learner to an expert able to go beyond imitation to contributing new ideas. The main problem with apprenticeship learning is that the highly personalized support required from expert mentors significantly limits scalability and access.

2.1.4 Situated learning and legitimate peripheral participation. A less mentor-intensive approach is to learn in communities of practice. Lave and Wenger [46] argued that learning also includes the norms and practices of a workplace or other community and should thus be situated in these contexts. In their theory, newcomers obtain opportunities for authentic work and get support for learning through legitimate peripheral participation (LPP) [46, 80], in which novices carry out simple, but authentic real-world tasks at the periphery. It is these peripheral tasks that provide novices with the opportunity to become part of the community, to understand their practices, and to gradually learn from those who are more knowledgeable as they ostensibly move from peripheral to core tasks. The problem is that there are sometimes no clear pathways to go beyond peripheral to core tasks because there is no mentor dedicated to scaffolding work for the learner. This can be seen in open source, the most widely cited example of LPP [51, 59]. While maintainers often label "low-hanging fruit" [30] such as fixing bugs or documentation that provide newcomers with opportunities to participate, newcomers face numerous participation barriers to going deeper [29, 67, 75] with most core development done by a few long-term contributors [50]. "Many projects generating widely downloaded FLOSS resources are, in fact, the products of firms or individuals working alone" [2, 64].

2.1.5 Distributed apprenticeship learning. Our approach is most directly inspired from Hui, Easterday, and Gerber's study of distributed apprenticeships, which observed that the social affordances of online crowdfunding communities can provide aspects of apprenticeship learning in a distributed and scalable manner [37]. Our project is similarly interested in designing an environment whose social affordances enable it to help large numbers of learners obtain apprenticeship-like learning support. The challenge is to provide an environment for learners to predictably progress from simple (potentially peripheral) tasks to mastery over core aspects of a complex skill through access to scaffolded authentic real-world tasks that enable them to keep working and learning in their (evolving) ZPD, and guided support for successfully completing and learning from these tasks through reflection. Unlike distributed apprenticeships that take place in online communities, however, we would like to design this in a classroom context orders of magnitude smaller than that of typical online communities and where one needs to provide scaffolded guidance to every learner.

2.1.6 Service learning. One form of experiential learning particularly relevant to our project is service learning, a pedagogical model or approach in which experiential learning takes place in the context of service to the community [39]. The main difference in service learning (as compared to other forms of experiential learning) is that the learning objective does not only center on building technical skills, but also on building civic skills and responsibility. Reflection often goes beyond building models of ideal (technical) practice to thinking about connections between academic knowledge and community/societal practices to critically reflecting on systemic issues in society and how what they are learning might help facilitate desired change.

Service learning is also not only centered on student learning, but emphasizes benefiting community partners too in equitable, reciprocal partnerships. Because students need to deliver real value to partners, projects can be richer and more real-world than other forms of experiential learning. However, it also means that in addition to the challenge of providing personalized mentorship to students at scale, service learning also faces the challenge of aligning community needs with student learning [24, 49]. One intriguing new model, Community-Initiated Student-Engaged Research (CISER), shows how one can engage large numbers of students in service learning projects by connecting faculty research, student learning, and community service [27]. We will come back to this later in discussions.

While service learning has grown in prevalence in the humanities and social sciences, potentially due to its strong synergies to critical pedagogy [15], it has been limited in engineering, where a focus on developing technical skills and differences in teaching methods, styles, and assessment procedures have acted as additional barriers to the adoption of service learning [5]. We are interested in developing models of experiential, community-engaged learning that can successfully align student learning to supporting community needs in the context of large engineering courses.

2.2 Crowdsourcing and emerging technologies for experiential learning

We have reflected on how experiential learning works, what is needed to provide it at scale, and why doing so has remained challenging. We now examine the literature on crowdsourcing and computationally mediated work through this lens to explore the potential they have for supporting experiential learning and what is still needed.

2.2.1 Crowdsourcing and existing connections to learning. Crowdsourcing is the process of accomplishing desired objectives by tapping into the power of the crowd, often through digital platforms [36]. At first glance, crowdsourcing is the last place one would look to for learning. Crowdsourcing today is mostly devoid of learning and career development for the worker [61], characterized by simple repetitive tasks carried out in isolation [8], and optimized for requester outcomes to the detriment of the worker [38, 65].

Nevertheless, crowdsourcing offers potential for experiential learning because, at its core, much of crowdsourcing is concerned with enabling novice participants to complete real-world work. As a result, many have studied how learning can support crowdsourcing. For example, a thread of research centers on designing synergistic alignments between crowdsourcing and other activities so that crowdsourcing happens as a natural outcome of playing games [13, 73, 74], pursuing hobbies [47, 68], participating in a community [41], or even filling out Buzzfeed-like surveys [58]. In this context, learning has emerged as a natural activity that can be aligned with crowdsourcing goals (see learnersourcing [40]), with projects ranging from translating the web through language learning [72] to generating explanations [81], hints [25], and labels [79] through learners in MOOCs. Second, incorporating learning into crowdsourcing processes has been shown to support higher-quality novice work. For example, rubric-supported peer feedback [20, 82] or visibility into top peer work [19] can help learners as much as similar support from experts, leading researchers to study the integration of tutorials [18] or peer coaching [9] to improve crowdsourcing.

But not only is learning able to support crowdsourcing, crowdsourcing is also able to support learning by providing a source of authentic real-world work for experiential learning, e.g. by repurposing crowdsourcing tasks as micro-internships [69] or by connecting crowdwork to traditional MOOCs [44]. One challenge, however, is that crowd workers run into the same barriers as learners trying to make significant contributions in an experiential project-based course: it is hard for novices/learners to do work they are not already familiar with, but it is difficult to obtain mentorship from a more knowledgeable other that might support them in doing so. This is why crowd workers are traditionally are only able to obtain simple tasks to work on (e.g. in micro-task platforms like AMT) or ones for which they already have expertise (e.g. in freelance platforms like Upwork). To understand how we might resolve this, we turn to the literature on complex crowd work and the innovations in computationally-mediated work that made it possible.

2.2.2 Complex crowd work and computational ecosystems. Traditionally, crowdsourcing centers on completing independent collections of simple tasks [22, 26, 32, 54]. To support more complex goals, researchers invented micro-task workflows [48], a way of coordinating work through decomposing complex goals into small tasks. Importantly, this decomposition needed to take human factors into account to ensure that novice workers could successfully complete the tasks, and in ways that could be built upon by others despite lack of context. This resulted in a significant literature on patterns for decomposing complex goals and on workflows for increasingly complex objectives such as taxonomy creation, shortening essays, or real-time support of blind users [3, 4, 10]. This was later found to still be insufficient for even more complex goals, leading researchers to shift towards studying expert crowd work on freelance platforms and to invent new organizing structures such as computationally-enhanced teams and organizations that were better suited for sharing context in complex work [60, 62, 71, 84].

The lesson we want to draw from this is that the development of computationally-mediated structures for work made it possible to organize novices to achieve increasingly complex goals. Thus far, these structures have mostly centered on achieving outcomes for requesters, leaving novice workers still stuck doing simple, peripheral tasks with little upskilling. Might it be possible to develop analogous structures for organizing complex work that also center the needs of learners? Can we develop structures that enable novices to reliably carry out complex work, decompose complex work into smaller roles that can guide learners in acquiring complex skills, and facilitate guided support for all learners from the community of learner-contributors of a project.

Some work has begun to explore computationally-enhanced ecosystems that support learners at scale in research projects [70, 83]. This project seeks to contribute to this emerging area and to surface challenges and research directions that can enable experiential, community-engaged learning at scale. Finally, we note that the opportunity is not only to design organizing structures that support learning and complex collaboration, it is also to design ecosystems that support relationship-building and incentive alignment across campus and community stakeholders. In digital civics, researchers have pointed out that a major challenge of designing for cities and communities is finding ways to support and foster relationships, trust, and alignment [1]. As will be discussed later, our design iterations of a course-based community consultancy not only explored new organizing structures within a classroom, but also ways to connect to and support broader ecosystems and collective impact systems across campus and in the community.

3 METHODS

Our research followed a design-based research process [34, 63, 85] in which we evolved the structure of a central course by repeatedly running in-the-wild prototypes, learning from the experience through observation, surveys, grades, and student interactions, and then updating our model accordingly for the subsequent iterations. We designed with the following goals in mind: 1) to increase access to rich experiential learning with apprenticeship-like mentorship dynamics, and 2) to ensure that the time put in by community partners was well worth their time, i.e. that students were able to deliver sufficient value to their clients given the time they put into participating in interviews, project feedback sessions, or other tasks.

Our design iterations took place over three iterations of a "business strategy and information systems" course at a large public research university in Spring 2021, 2022, and 2023. The 10-week quarter-long course is part of the major requirements for an interdisciplinary major in the engineering division and centers on understanding business strategy and the use of digital tools in organizations (more details about the course content and structure later). The course is one of the most diverse in engineering. Across the three offerings mentioned, our 352 students were 28.2% first generation college students, 31.6% female or non-binary, 12.6% underrepresented race or ethnic groups, 27.6% with pell grants, and 20.3% transfer students. Most students had senior status (72.4%) and were engineering majors (81.3%), but there were also a non-trivial number of students (20.3%) from either the arts or the social sciences. Due to our goal of providing access to all, the instructor (also the author) accepted all students off the waitlist who wanted to participate.

As will be discussed later, rather than having student teams serve multiple different community partners, we organized the entire class around delivering a single large "strategic assessment and design exploration" project for a single community partner that consisted of multiple smaller projects. Our community partners were drawn from a pilot matchmaking process that we ran in Fall 2020 and Winter 2021 in which we conducted intake interviews with community members interested in working with student programs, sought to understand their project needs and interests, and then supported them in connecting with the various programs on campus to find one with a good fit. Our Spring 2021 client was an arts related non-profit and our Spring 2022 client was a youth education related non-profit. Both had gone through our matchmaking process during which we connected them with an existing campus program who helped them with their online presence. Because we had already conducted 90-minute intake interviews with them through the matchmaking program, we already had a broad sense of their organizational context, needs, and interests when we reached out to them about participating in our course-based community consultancy project. In Spring 2023, to better iterate on our model towards our idealized goals, we decided to work with the same two non-profit clients to build on and improve the projects from previous years to evaluate and further refine improvements we made to the course structure and process since the early iterations.

4 DESIGNING OUR COURSE-BASED COMMUNITY CONSULTANCY

4.1 Overall approach: structuring learning after the workplace

In our model, the experiential learning goals of a course are defined in terms of a significant project with a much larger real-world scope than what students typically encounter. This project is decomposed into smaller milestones which are in turn decomposed into one-week assignments corresponding to experiential micro-roles organized through structures such as hierarchy, divisions, teams, Gantt charts, and learning pathways (we will elaborate on this further in **Section 4.3**). This project decomposition and organization needs to enable learners to steadily acquire skills while also successfully delivering high-quality project outcomes. The various parts of the course are then structured around supporting learners in completing and reflecting on the experiential micro-role based work. For example:

- *Lectures*, which are 95-minutes long twice-a-week, include traditional teaching of fundamental concepts, but are also used for modeling and critiquing roles or for client interaction,
- *Sections*, which are 65-minutes long once-a-week, are used as student work sessions for joint deliverables,
- *Assignments*, which are weekly, involve completing roles, and can sometimes differ for different individuals in a given week based on past progress or project needs. Roles can have different due dates so that different students could be conducting interviews, analyzing them, and synthesizing analyses one after another in a single week, making it possible to accomplish more than in a traditional structure.
- *Tutoring and grading*, done by graduate and undergraduate students, centers on critiquing and guiding project work towards a high-quality client deliverable, with staff taking on management-like roles,

The goal is to create an experience like the workplace where learning centers around advancing and iterating on work to deliver a high-quality real-world project to clients.

4.2 Core components: strategic assessment and design exploration

The project we centered our course around was to deliver a large ‘strategic assessment and design exploration’ project for a nonprofit (see **Figure 1**) consisting of the following parts, each of which evolved over our three iterations:

- *Landscape Analysis.* This centered on surfacing and synthesizing internal perspectives of the organization and involved surveying and interviewing dozens of board members, staff, and core volunteers, conducting a thematic analysis of this data, and synthesizing it to understand the organizations’ core values and perceived organizational strengths, weaknesses, opportunities, and threats.
- *Stakeholder Experience.* This centered on surfacing and synthesizing external perspectives of the organization and involved surveying and interviewing dozens of clients, conducting a thematic analysis of this data, and synthesizing it to understand the stakeholder experience including their motivations, the process of discovering the organization, engaging in and experiencing its services, and growing or ending their engagement.
- *Future State Design.* This varied more widely from year-to-year, but overall centered on defining the organization’s strategic position, brainstorming problem statements and ideas, and scoping out potential project ideas through sketching, product/creative briefs, or “working backwards” press releases. Project ideas included ones provided by clients as well as ones proposed by students.

- *Design Exploration.* This also varied more widely from year-to-year, but centered on student teams implementing or prototyping different mini-projects that use digital tools to support organizational needs. These included social media marketing campaigns, database and workflow development, and website and app design and development. We also had some student teams refining or expanding work from the needs assessment or ideation parts of the course.

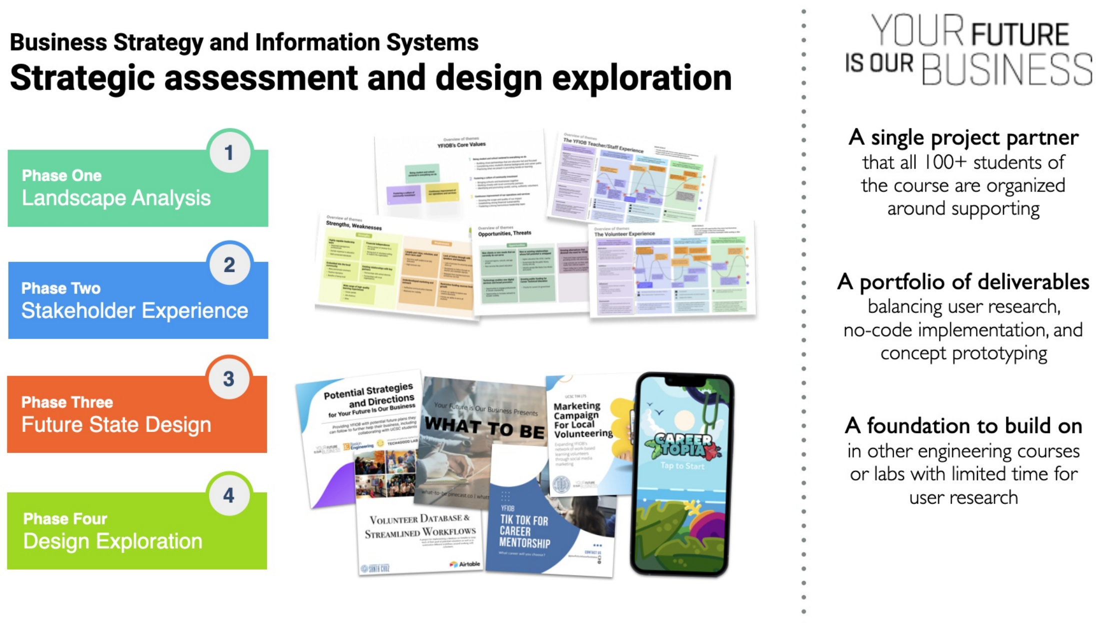

Fig. 1. We organize a large class around delivering a single large consultancy project for a nonprofit client with four parts that together deliver a diverse portfolio of outcomes that can also be built on in future collaborations between the client and campus.

As can be seen, the scope of the project is very large for a 10-week course (one professional consultant said the scope was a $1 million project), and is only possible due to the structure of the course used to coordinate 100+ students towards delivering an ambitious project. It aims to provide large numbers of students with a rich real-world experience of designing technology-oriented projects grounded in a deep understanding of an organization's strategic needs and the needs of its users, and to enable instructors to support the large number of students.

In the remainder of this section, we will describe what we converged to in our design iterations across the various parts of our course, and the reasons for these choices. **Section** 4.3 describes how we iterated on the Landscape Analysis and Stakeholder Experience components, with a focus on evolving the role structures for coordinating collaborative work. **Section** 4.4 describes how we iterated on the Future State Design and Design Exploration components, with a focus on exploring different project types that could best connect student learning to community outcomes. Finally, **Section** 4.5 describes early efforts to design the project outcomes and experiences to also connect to and support other campus-community projects around technology for the public interest. These will be followed by a discussion of broader implications and lessons learned in **Section** 5.

4.3 Designing the landscape analysis and stakeholder experience components

Given the short 10-week quarter, one of the major tensions we had to work under was how to balance the desire to have students dive deep into understanding diverse aspects of the organization and its stakeholders and to deliver high-quality synthesized analyses around needs assessment, and the desire to leave sufficient time for interesting design exploration mini-projects. This is particularly challenging because many students don't come in excited to spend significant time rigorously analyzing qualitative data, and would rather quickly jump into the mini-projects. In what follows, we describe the structure we converged to (so far) for the landscape analysis and stakeholder experience (both of which followed the same structure) and what motivated these choices. One thing we'll caveat these discussions with is that some choices are unique to our constraints, so may not be the best for all contexts. For example, in a semester-long course or a multi-quarter project sequence, where one is not as time constrained, one might make different choices.

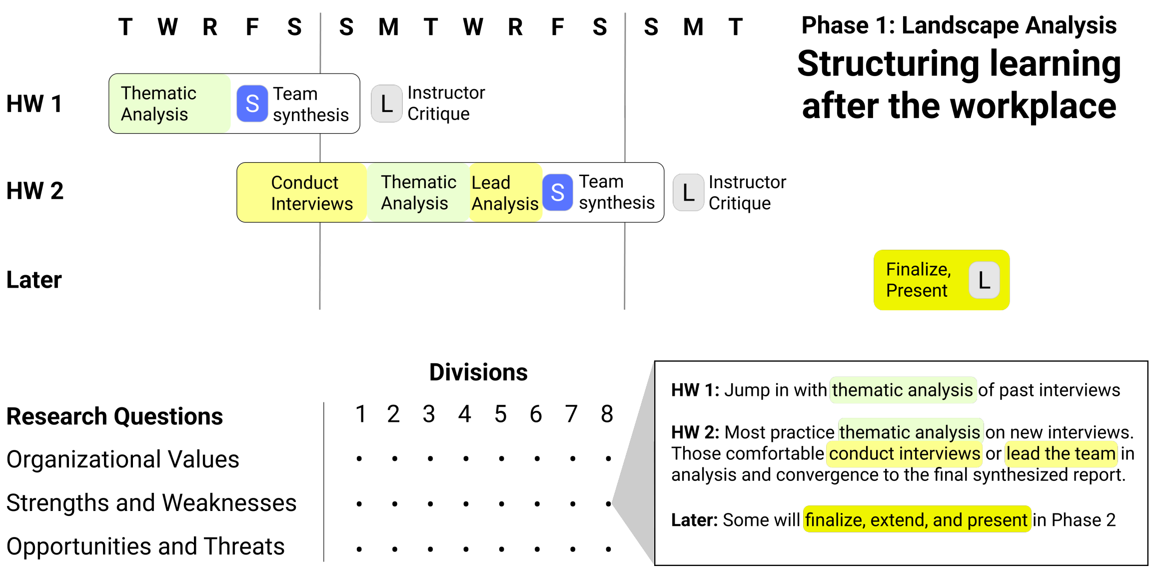

Fig. 2. In our landscape analysis and stakeholder experience phases, students are organized into divisions, each delivering an independent analysis and each composed of three teams focused on specific research questions. Students conduct individual analyses and then discuss and converge as a team. In the second week, students may work on different roles.

4.3.1 *Jump in with pre-conducted interviews.*

One thing we did that worked well was to have the instructor conduct 2-4 interviews before the class started for students to analyze rather than the typical approach of having students conduct their own interviews to analyze. This helped in two important ways. First, it saved a lot of time, giving us more room for in-depth analysis. If students had conducted these initial interviews themselves, they would not only need time for interviewing, they would also need additional time to ramp up on the organizational and project context. By jumping into analysis on day 1, they naturally built context for the client. Second, our approach allowed them to build intuition in qualitative research, understand the importance of going deep in eliciting stories, and better understand the research questions, natural first steps before learning to conduct interviews.

4.3.2 *Use the pattern: individual analysis, team synthesis, instructor critique.*

A pattern we converged to was to have every individual submit their own analysis, followed by a team deliverable in which they had to discuss and synthesize their work, followed by instructor critique of 1-2 teams doing the highest-quality work, all in a one-week timeframe. Individual submissions were due before sections so that they could use sections to discuss and converge on a common set of themes and to fill out a report template. This pattern ensured that every individual was learning, facilitated peer learning, and also narrowed down the submissions to a smaller number of higher-quality submissions for instructor critique. Over the years, we also evolved the instructor critique to not only consist of discussing student work, but to also involve directly editing and iterating on student themes, similar to the dynamic of a manager overseeing an intern or a faculty mentoring a research team in an authentic real-world qualitative research project. This was important for modeling ideal practice and for moving the work towards a high-quality outcome. After we had a good example from prior years, we also used this to discuss and model ideal practice before the assignment, another significant factor in increasing the quality of student work.

4.3.3 Use a matrix team structure to reduce workload. While the individual and team submissions are intended to be equivalent to a single assignment each week (with the team submission designed to basically consist of discussing and synthesizing individual work), having two deliverables can make for a heavy workload, and the first week is a sharp ramp-up. One thing that helped was that we began to organize teams in a matrix structure, so that each student was assigned to a team that was only responsible for conducting analyses for a single research question. These teams were organized within larger divisions (of one team per research question), all of whom belong to the same section time. This enables team leads to easily coordinate with each other when delivering a common report and presentation. One thing we plan to do in the future is to carve out time during lecture for students to review and critique the analyses from other teams to give them exposure to the other research questions.

4.3.4 Use multiple roles per week when appropriate. After students complete one round of analysis in week 1, we had them do a second round of analysis to improve their skills and expand the set of interviews conducted for the client project. Unlike the first week, these second set of interviews are conducted by a subset of the students, though the interviewees are recruited and pre-scheduled by course staff to land within a 2-day timeframe after the individual thematic analyses from week 1 are complete. This second week entails having students in different roles. Some students conduct and transcribe the interviews, most do another round of thematic analysis on the new interview transcripts, while other students take on a leadership role in the final team synthesis and presentation of the work. Students are assigned to conduct interviews based on interest and availability from an intro survey filled out before the start of class, and we also check that their individual thematic analysis work in HW 1 demonstrates understanding of qualitative research. Students assigned to leadership roles are drawn from those who did the best work in the HW 1 individual submission, providing those doing well with new learning opportunities and those who need to improve with additional practice. If we are not able to schedule a student, we have undergraduate course staff conduct the interviews.

4.3.5 Other choices made around content and scope. The previous items we mentioned all center on role-based structures that we evolved for organizing students in each of the 2-week long analysis components of the course. We find those the most interesting to highlight from the perspective of opportunities for designing novel organizational course structures. However, there are also other ways in which we evolved this portion of the course.

- First, in our early iterations, we integrated a one-week ideation component into the end of the landscape analysis and stakeholder experience portions, making each 3-weeks long. This was not ideal, however, because it made it even more challenging to get students to appreciate spending time rigorously and deeply understanding the organization. As students brainstormed ideas, they wanted to move onto implementation, and it was psychologically demotivating to have 6 weeks of the schedule taken up by what looked to be analysis. Separating out ideation and keeping analysis focused on analysis helped with this,

- A second thing we evolved was how we wrapped up the final deliverable. We realized that student reports still often required multiple rounds of feedback to polish final reports to reach the quality we wanted. Even if each round of feedback did not entail a lot of work, it still meant that reports would not be finalized until many weeks after. Our approach now is to have a team of students interested in continuing to polish the analyses do so during the design exploration phase and have a student staff member assigned to work with them to deliver a high-quality outcome. The instructor also takes some time during lecture to critique their work and to model iterating on parts of the report towards high-quality outcomes.
- A third thing we want to do in the future (but have not done yet) is to incorporate client feedback into creating the final report. Stakeholders in the organization sometimes want to add clarifying comments or reactions to contextualize surfaced themes in the final report such as weaknesses or negative client experiences, and we see this as something important to be responsive to.

4.4 Designing the future state design and design exploration components

The future state design and design exploration components involved having students split up to work on multiple different mini-projects. The major challenge in this portion was how to ensure that student learning was also aligned with delivering sustainable value to community partners. Unlike the landscape analysis and stakeholder experience components, where non-profit clients benefit from the data collected and synthesized insights of internal and external stakeholders, projects that have students work on prototyping or implementing digital tools are more challenging for resource-strapped non-profits to learn and maintain after the end of the class. A second challenge is that because the projects are all different, it can be difficult to guide them all. Our design iterations focused on what types of projects can best align student learning goals and community project needs, how to define the set of mini-projects for a given client, and how to provide weekly guidance to support the many different projects. In what follows, we describe what we converged to (so far) and what motivated these choices.

4.4.1 Have a diverse portfolio of projects helps to balance student and community client needs. One thing that helped a lot in establishing a successful partnership with community clients was to have a diverse portfolio of projects across the class. Some projects were ones that the non-profit partner specifically requested, while others were ones defined by students or the course staff. Some projects were ones that we were confident could deliver immediate value to the partners, while others were just prototypes of concepts that could spark ideas but were unlikely to be actually implemented given realistic resource constraints. Having this diverse portfolio ensured that clients could be confident that the outcomes would be well worth their time while also providing flexibility to have projects focused on supporting student creativity or exploration.

4.4.2 Consider using no-code / low-code tools. We have found that no-code / low-code tools are particularly helpful in supporting projects that can deliver immediate value to partners. For example, we always have some students interested in designing new mobile apps that can support the organization's mission or client needs. In early days, we had students end with delivering an interactive digital prototype in Figma, but while this helped with exploring and visualizing concepts, there was no realistic path for the small non-profits we worked with to get it actually built out. In our latest iteration, we had students making mobile app prototypes use no-code / low-code tools like Softr and FlutterFlow that can produce a version of the concept that can be immediately deployed and used (if simple enough).

We also have student teams working on implementing databases (e.g. using tools like Airtable) and automation software (e.g. using tools like Zapier and Make) to support internal processes and workflows. Students working on these get to learn to organize data into relational database-like schemas and to write small scripts, but they are much easier for community clients to use and maintain (though we note that even these require significant documentation and hand-off support, and initially are overwhelming to nonprofit clients). The nice thing is that these tools can also be connected to the mobile app prototypes so that non-profit clients can also have a usable interface to work with the backend data connected to the mobile app prototypes. Finally, we have students who are developing initiatives or services for the non-profit that don't require a completely new mobile app, but can be supported on a more traditional website like Wordpress or Webflow, or running marketing campaigns on social media and exploring content generation using generative AI. All of these are engaging for student learning and also likely to deliver value to community clients.

We acknowledge, of course, that this worked for our particular course context, but likely wouldn't be suitable for many engineering project-based courses. We will return to this later when we discuss how the outcomes of this course can potentially be used as a starting point to support other engineering courses.

4.4.3 Incorporate content generation or outreach components that leverage the large class size. Sometimes we may not be confident that the overall project will be valuable to the client, but can still design it to include content generation or outreach components that we are confident will deliver value just by leveraging the size of the class. For example, one non-profit had a podcast containing interviews of different career professionals. Students listened to hundreds of these interviews, curated mini-clips that captured interesting career insights, and then used these for a new product concept for helping youth explore careers. Even if the actual product concept delivered didn't end up being used (though in this case it was), the curation of all the mini-clips was still valuable for community clients and was not onerous for students when divided up among a large team. Similar value can also be produced through adding outreach components, e.g. to create visibility or build partnerships within the community around an initiative.

4.4.4 Integrate with local collective impact funding programs. One thing we did in our latest iteration which was extremely valuable was to tie all our efforts into a local collective impact funding program for the county, Santa Cruz CORE investments. This program provides $5 million worth of community grants each year to local programs through a framework that encourages data collection and data sharing to enable measurement of progress towards collective impact goals and sharing of effective strategies. It requires grantees and applicants to clearly specify measures and data collection processes, and to demonstrate how they are improving their services through a data-oriented approach.

When we reoriented and reframed our various projects around supporting them in becoming more competitive for CORE, they all became much more attractive because it now supported a short-term goal of obtaining grant funding as well as long-term ones. Our thematic analyses not only provided insights, but also provided qualitative data for the grant. Implementation of surveys or other processes for understanding the experience of those using their services became progress towards CORE goals that could be cited. Databases became more useful for helping with collection, organization, analysis, and visualization of metrics.

4.4.5 Use lectures for project guidance and peer/client feedback. This second portion of the class was harder to guide because it contained so many different project types. While in the ideal scenario, we would love to have a set of pre-determined project types that each explicitly break down goals into individual roles and collaboration dynamics like what we did in the analysis portions, that is much farther away. However, we found that we were still able to give sufficient guidance through a combination of different strategies. Besides specifying high-level milestones that apply across all project types and having undergraduate and graduate teaching staff meet regularly with project teams, we also repurposed almost all of the lecture times as either project check-ins or project fairs for peer/client feedback. We had teams maintain an ongoing “risk board” of the biggest priorities they had for their project and the instructor would check-in on these risks during these project check-in times. Feedback provided for a given project type also contained transferable lessons for other teams. We also had four “project fairs” in the 6 week period for students to interact with peers and clients. Students first had a peer feedback fair centered on their first prototype implementation of their project followed by a client feedback fair. They later had a second set of peer and client feedback centered on ensuring successful hand-off of the project to clients beyond the course. These were invaluable for guiding student teams.

4.4.6 Assign students to project types during ideation and integrate it with project specification. In early iterations, projects and project teams were only determined after we had generated and converged on ideas, but this left only 4 weeks to actually work on the projects, and more importantly, to iterate on them in response to client feedback. In the context of our short 10-week timeline, we are converging to a process in which students are already assigned to specific project types (based on survey preferences) when starting ideation. This makes it possible to already begin scoping out project concepts and planning project milestones during the ideation weeks to transition more quickly into project implementation. The tradeoff, of course, is that this does not allow for as much time in teaching a rigorous ideation process and may also narrow the space of ideas explored.

4.5 Designing the project to connect to and support other campus-community projects

One final note we would like to end our reflections on design iterations is that we also began to explore how we might connect the efforts and outcomes from this main course to supporting other campus-community projects. Many engineering courses struggle to ground projects in a deep understanding of an organization’s needs because they need to focus the bulk of the quarter on ramping students up on technical aspects of the project. Because we spend a significant amount of time surveying and interviewing dozens of the organization’s stakeholders, understanding their strategic goals and position, and exploring a diverse set of ideas and projects, there is a potential to re-use some of that work to help other programs wanting to partner with the same community organization. While we are still early in exploring this, we did take some small steps that we can share.

4.5.1 Use generated content to bootstrap other project-based courses. We found it useful to reuse the generated interviews (with interviewee permission) in a separate “human-centered design research” course to help bootstrap the course (in Winter 2022 and Winter 2023). This course guides students through the process of understanding needs, brainstorming ideas, and storyboarding and iteratively prototyping designs for mobile applications from low-fidelity to high-fidelity and interactive prototypes. Being able to reuse interview transcripts allowed students to immediately jump into understanding needs relevant to the theme for that quarter (e.g. advancing the arts or supporting youth education). Even though the interviews were carried out for one specific organization, they reflect needs across diverse stakeholders and contain insights for the problem area beyond that specific organization. Because students were able to quickly immerse themselves in these rich perspectives, we were able to have them generate storyboards for multiple concepts that they could use to elicit further perspectives and insights when conducting subsequent interviews. Some student teams worked on projects relevant to the same organization and so were able to directly build on prior work. However, student teams who end up working on other ideas with other community stakeholders also benefited by being able to jump start conversations much more quickly. We believe this could also benefit capstone courses, web development courses, mobile app development courses, other project-based courses or even hackathons that don't currently have students engage with users before working on project ideas.

4.5.2 Link needs assessment to scoping out new research projects. In one of our design iterations, we had some undergraduate students engaged in the course (either as students or teaching staff) who were also interested in HCI research. We created a team out of these students within the instructor's research lab and gave them additional independent study credits to begin reading HCI papers around the topic of youth education while they were also participating in the needs assessment portions of the class. As they developed intuition around the community partner's needs and intuition around the research literature, they identified recent papers in the literature that intersected with observed needs and brainstormed follow-up projects that could extend ideas in those papers. This has resulted in two developing research projects. We see an opportunity for the course-based community consultancy to also seed community-engaged research projects that can carry on for much longer time periods as compared to the quarter-long projects of the course.

4.5.3 Expand events to invite in other relevant stakeholders. Finally, one other approach we see as an interesting way to support other campus-community projects is to simply invite in other people on campus working in areas likely to interest our community clients. For example, even though the project fairs mostly center on student projects in the course, we invited in students from two research labs also working on supporting youth education to share about their project. As discussed previously, one of the major strengths of our project is that we found ways to have a large portfolio of projects, some of which we are highly confident will deliver immediate value to clients. Academic research projects often don't have that advantage, and are more long-term in nature, making it more difficult for them to engage community partners in ways that advance their own research goals while also ensuring outcomes worth the community partner's time. Inviting them into events helps them overcome this problem.

5 DISCUSSION: BROADER IMPLICATIONS AND DESIGN DIRECTIONS

5.1 Large and diverse classes can be a strength for experiential, community-engaged projects

A major motivation for this project was wanting to tackle the challenge of expanding access to opportunities for experiential, community-engaged learning to better equip students for the workforce and to train them in developing technologies for the public interest. One of the biggest conclusions we took away from these multiple years of iteration is that a large and diverse class can actually be an strength rather than a weakness in working towards this goal. We saw several ways in which this played out. **First, a large class allows for redundancy in the work being done, both within teams and across teams**. We did this by having multiple individuals work on the same tasks and then asking them to discuss and converge. We also did this by having multiple teams work on independent versions of the client deliverable and allowing them to critique and build on each other's work. Both of these provided a context for peer learning while also increasing the likelihood that at least one student or team would achieve high-quality outcomes for the client. **Second, a large class allows for a diverse portfolio of projects that can help align student learning and community outcomes**. The large class makes it possible to engage in a robust needs assessment process where students interview and analyze dozens of stakeholders to ground projects in a deep understanding of client needs and contexts. The large class also makes it possible to work on projects requested by clients along with projects proposed by students or staff, or projects that provide immediate short-term value along with projects that invest in longer-term needs or just explore concepts. Sometimes, these longer-term exploratory concepts are a better fit for the learning goals of some students, but would not provide sufficient value to community clients on their own. **Third, a large and**

diverse class is able to benefit from diverse lived experiences in needs assessment and ideation. While we did not have any formal measures of this, there were multiple times when we observed that different students' lived experiences allowed them to better empathize with particular needs in those we interviewed for the non-profits. This is something promising to more intentionally look into for the future.

5.2 A course-based community consultancy can contribute to collective impact efforts

In the earliest stages of the project, our goal centered on expanding access to experiential, community-engaged learning. However, as we developed the course, we began to see opportunities for the course to not only be a valuable experience in itself, but to also play a role in supporting a broader university-community ecosystem, and to contribute to and benefit from collective impact. We saw this in multiple ways. **First, the in-depth needs assessment process can produce content that can bootstrap other project-based courses and community collaborations**. We did this by re-using interviews and analyses to bootstrap needs assessment and concept generation in a human-centered design research course, making it possible for students in a short 10-week quarter to have multiple opportunities to engage with user data. Other engineering courses could potentially benefit even more, as students sometimes work on completely made-up projects that are not rooted in client needs. Imagine if a student in a mobile app development course could instead work on building out a validated concept wanted by a community client and already previously prototyped. **Second, the strong value the course is able to deliver to community partners gives it an opportunity for facilitating new connections**. While research projects might otherwise face challenges aligning long-term research goals with impact for community partners, when they are included in the larger portfolio of projects being delivered by the class, it is easier for community partners to get excited about engaging in discussions around those ideas. We found that the course project fairs were great contexts for facilitating interaction between relevant campus projects and community clients or other community stakeholders interested in similar topics. **Third, the course has particularly strong synergies with local community collective impact funding initiatives**. In our case, connecting our analyses and projects to the Santa Cruz Collective of Results and Evidence-Based (CORE) Investments helped provide additional alignment for non-profits around the projects because they now provided an added short-term benefit of helping the non-profits strengthen their position for obtaining a CORE grant. On the flip side, our project also supports the CORE initiative by helping support non-profits in developing a data-oriented approach to measuring their impact and improving their services based on collected data.

6 CONCLUSION

In this paper, we discussed design iterations over a three-year long period for developing a course-based community consultancy to expand access to experiential, community-engaged learning and promote equitable campus-community partnerships that deliver sustainable value to community partners. We reviewed literature in experiential learning, crowdsourcing, and collaboration to motivate the opportunity we see for developing new design patterns for structuring learning around the workplace through organizing a large class as a collaborative organization. We described lessons learned in iterations on different parts of the project that help demonstrate how role-based structures can help to facilitate learners around significant project contributions and how projects can be designed to align student and community needs. We propose that large and diverse classes can be a strength for experiential, community-engaged projects, that the course-based community consultancy model can contribute to collective impact efforts, and that rich directions exist for design to think about how learning can be organized around work in a way that meets needs for student upskilling and the development of public interest technologies in equitable community partnerships.

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REFERENCES

[1] Mariam Asad, Christopher A Le Dantec, Becky Nielsen, and Kate Diedrick. 2017. Creating a Sociotechnical API: Designing City-Scale Community Engagement. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 2295–2306.

[2] Yochai Benkler, Aaron Shaw, and Benjamin Mako Hill. 2015. Peer production: A form of collective intelligence. *Handbook of collective intelligence* 175 (2015).

[3] Michael S Bernstein, Greg Little, Robert C Miller, Björn Hartmann, Mark S Ackerman, David R Karger, David Crowell, and Katrina Panovich. 2010. Soylent: a word processor with a crowd inside. In *Proceedings of the 23nd annual ACM symposium on User interface software and technology*. dl.acm.org, 313–322.

[4] Jeffrey P Bigham, Chandrika Jayant, Hanjie Ji, Greg Little, Andrew Miller, Robert C Miller, Robin Miller, Aubrey Tatarowicz, Brandyn White, Samual White, and Others. 2010. VizWiz: nearly real-time answers to visual questions. In *Proceedings of the 23nd annual ACM symposium on User interface software and technology*. dl.acm.org, 333–342.

[5] D W Butin. 2006. The limits of service-learning in higher education. *The review of higher education* (2006).

[6] Julia Cambre, Scott Klemmer, and Chinmay Kulkarni. 2018. Juxtapeer: Comparative Peer Review Yields Higher Quality Feedback and Promotes Deeper Reflection. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. ACM, New York, NY, USA, 294:1–294:13.

[7] J Cambre, C Kulkarni, M S Bernstein, and others. 2014. Talkabout: small-group discussions in massive global classes. *Proceedings of the first* (2014).

[8] Yiling Chen, Arpita Ghosh, Michael Kearns, Tim Roughgarden, and Jennifer Wortman Vaughan. 2016. Mathematical foundations for social computing. *Commun. ACM* 59, 12 (Dec. 2016), 102–108.

[9] Chun-Wei Chiang, Anna Kasunic, and Saiph Savage. 2018. Crowd Coach: Peer Coaching for Crowd Workers' Skill Growth. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW (Nov. 2018), 1–17.

[10] Lydia B Chilton, Greg Little, Darren Edge, Daniel S Weld, and James A Landay. 2013. Cascade: Crowdsourcing Taxonomy Creation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Paris, France) *(CHI '13)*. ACM, New York, NY, USA, 1999–2008.

[11] Allan Collins. 2006. Cognitive apprenticeship. In *The cambridge handbook of the learning sciences*, R Keith Sawyer (Ed.). Cambridge University Press.

[12] Allan Collins, John Seely Brown, and Susan E Newman. 1989. Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. *Knowing, learning, and instruction: Essays in honor of Robert Glaser* 18 (1989), 32–42.

[13] Seth Cooper, Firas Khatib, Adrien Treuille, Janos Barbero, Jeehyung Lee, Michael Beenen, Andrew Leaver-Fay, David Baker, Zoran Popović, and Foldit Players. 2010. Predicting protein structures with a multiplayer online game. *Nature* 466, 7307 (Aug. 2010), 756–760.

[14] Cathy N Davidson. 2017. *The new education: How to revolutionize the university to prepare students for a world in flux*. Hachette UK.

[15] Thomas Deans. 1999. Service-Learning in Two Keys: Paulo Freire's Critical Pedagogy in Relation to John Dewey's Pragmatism. *Michigan Journal of Community Service Learning* 6 (1999), 15–29.

[16] John Dewey. 2004. *Democracy and Education*. Courier Corporation.

[17] John Dewey. 2007. *Experience And Education*. Simon and Schuster.

[18] Mira Dontcheva, Robert R Morris, Joel R Brandt, and Elizabeth M Gerber. 2014. Combining Crowdsourcing and Learning to Improve Engagement and Performance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. ACM, New York, NY, USA, 3379–3388.

[19] S Doroudi, E Kamar, E Brunskill, and E Horvitz. 2016. Toward a learning science for complex crowdsourcing tasks. *Proceedings of the 2016* (2016).

[20] Steven Dow, Anand Kulkarni, Scott Klemmer, and Björn Hartmann. 2012. Shepherding the Crowd Yields Better Work. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (Seattle, Washington, USA) *(CSCW '12)*. ACM, New York, NY, USA, 1013–1022.

[21] Thommy Eriksson, Tom Adawi, and Christian Stöhr. 2017. "Time is the bottleneck": a qualitative study exploring why learners drop out of MOOCs. *Journal of Computing in Higher Education* 29, 1 (April 2017), 133–146.

[22] Tim Finin, Will Murnane, Anand Karandikar, Nicholas Keller, Justin Martineau, and Mark Dredze. 2010. Annotating Named Entities in Twitter Data with Crowdsourcing. In *Proceedings of the NAACL HLT 2010 Workshop on Creating Speech and Language Data with Amazon's Mechanical Turk* (Los Angeles, California) *(CSLDAMT '10)*. Association for Computational Linguistics, Stroudsburg, PA, USA, 80–88.

[23] Allan Fisher, Jane Margolis, and Faye Miller. 1997. Undergraduate Women in Computer Science: Experience, Motivation and Culture. *SIGCSE Bull.* 29, 1 (March 1997), 106–110.

[24] Beth Gazley, Laura Littlepage, and Teresa A Bennett. 2012. What About the Host Agency? Nonprofit Perspectives on Community-Based Student Learning and Volunteering. *Nonprofit and Voluntary Sector Quarterly* 41, 6 (Dec. 2012), 1029–1050.

[25] Elena L Glassman, Aaron Lin, Carrie J Cai, and Robert C Miller. 2016. Learnersourcing Personalized Hints. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (San Francisco, California, USA) *(CSCW '16)*. ACM, New York, NY, USA, 1626–1636.

[26] Sandra González-Bailón, Javier Borge-Holthoefer, Alejandro Rivero, and Yamir Moreno. 2011. The dynamics of protest recruitment through an online network. *Sci. Rep.* 1 (Dec. 2011), 197.

[27] Miriam Greenberg, Rebecca A London, and Steven C McKay. 2020. Community-Initiated Student-Engaged Research: Expanding Undergraduate Teaching and Learning through Public Sociology. *Teach. Sociol.* 48, 1 (Jan. 2020), 13–27.

[28] Robert Greene. 2012. *Mastery.* Penguin.

[29] Christoph Hannebauer. 2016. *Contribution Barriers to Open Source Projects.* Ph. D. Dissertation.

[30] Christoph Hannebauer, Vincent Wolff-Marting, and Volker Gruhn. 2010. Towards a Pattern Language for FLOSS Development. In *Proceedings of the 17th Conference on Pattern Languages of Programs* (Reno, Nevada, USA) *(PLOP '10)*. ACM, New York, NY, USA, 15:1–15:10.

[31] I E Harel and S E Papert. 1991. Constructionism. (1991).

[32] Joseph M Hellerstein and David L Tennenhouse. 2011. Searching for Jim Gray: A Technical Overview. *Commun. ACM* 54, 7 (July 2011), 77–87.

[33] Paul R Hernandez, P Wesley Schultz, Mica Estrada, Anna Woodcock, and Randie C Chance. 2013. Sustaining Optimal Motivation: A Longitudinal Analysis of Interventions to Broaden Participation of Underrepresented Students in STEM. *J. Educ. Psychol.* 105, 1 (Feb. 2013).

[34] Christopher Plekss Hoadley. 2002. Creating context: Design-based research in creating and understanding CSCL. https://repository.isls.org/bitstream/1/3808/1/453-462.pdf. Accessed: 2021-9-16.

[35] Kate S Hone and Ghada R El Said. 2016. Exploring the factors affecting MOOC retention: A survey study. *Comput. Educ.* 98 (July 2016), 157–168.

[36] Jeff Howe. 2006. The rise of crowdsourcing. *Wired magazine* 14, 6 (2006), 1–4.

[37] Julie S Hui, Matthew W Easterday, and Elizabeth M Gerber. 2019. Distributed Apprenticeship in Online Communities. *Human–Computer Interaction* 34, 4 (July 2019), 328–378.

[38] L C Irani and M S Silberman. 2013. Turkopticon: Interrupting worker invisibility in amazon mechanical turk. *GROUP ACM SIGCHI Int. Conf. Support. Group Work* (2013).

[39] Barbara Jacoby and And Others. 1996. *Service-Learning in Higher Education: Concepts and Practices. The Jossey-Bass Higher and Adult Education Series.* Jossey-Bass Publishers, 350 Sansome St., San Francisco, CA 94104 ($32.95).

[40] Kim, Juho, and Ph. D. Massachusetts Institute of Technology. 2015. *Learnersourcing : improving learning with collective learner activity.* Ph. D. Dissertation. Massachusetts Institute of Technology.

[41] Juho Kim, Haoqi Zhang, Paul André, Lydia B Chilton, Wendy Mackay, Michel Beaudouin-Lafon, Robert C Miller, and Steven P Dow. 2013. Cobi: A Community-informed Conference Scheduling Tool. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology* (St. Andrews, Scotland, United Kingdom) *(UIST '13)*. ACM, New York, NY, USA, 173–182.

[42] René F Kizilcec, Andrew J Saltarelli, Justin Reich, and Geoffrey L Cohen. 2017. Closing global achievement gaps in MOOCs. *Science* 355, 6322 (Jan. 2017), 251–252.

[43] David A Kolb. 2014. *Experiential Learning: Experience as the Source of Learning and Development.* FT Press.

[44] Markus Krause, Doris Schiöberg, and Jan David Smeddinck. 2018. Mooqita: Empowering Hidden Talents with a Novel Work-Learn Model. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18, Paper CS14)*. Association for Computing Machinery, New York, NY, USA, 1–10.

[45] Chinmay Kulkarni, Koh Pang Wei, Huy Le, Daniel Chia, Kathryn Papadopoulos, Justin Cheng, Daphne Koller, and Scott R Klemmer. 2013. Peer and Self Assessment in Massive Online Classes. *ACM Trans. Comput. -Hum. Interact.* 20, 6 (Dec. 2013), 33:1–33:31.

[46] Jean Lave, Etienne Wenger, and Etienne Wenger. 1991. *Situated learning: Legitimate peripheral participation.* Vol. 521423740. Cambridge university press Cambridge.

[47] Chris J Lintott, Kevin Schawinski, Anze Slosar, Kate Land, Steven Bamford, Daniel Thomas, M Jordan Raddick, Robert C Nichol, Alex Szalay, Dan Andreescu, Phil Murray, and Jan van den Berg. 2008. Galaxy Zoo : Morphologies derived from visual inspection of galaxies from the Sloan Digital Sky Survey. (April 2008). arXiv:0804.4483 [astro-ph]

[48] Greg Little, Lydia B Chilton, Max Goldman, and Robert C Miller. 2009. TurKit: Tools for Iterative Tasks on Mechanical Turk. In *Proceedings of the ACM SIGKDD Workshop on Human Computation* (Paris, France) *(HCOMP '09)*. ACM, New York, NY, USA, 29–30.

[49] Laura Littlepage and Beth Gazley. 2013. Examining service learning from the perspective of community organization capacity. *Research on service learning: 2B Communities, institutions, and partnerships* (2013), 419–440.

[50] W Maass. 2004. Inside an open source software community: empirical analysis on individual and group level. *Proceedings of the 4th Workshop on Open Source* (Jan. 2004), 65–70.

[51] A Mockus, R T Fielding, and J Herbsleb. 2000. A case study of open source software development: the Apache server. In *Proceedings of the 2000 International Conference on Software Engineering. ICSE 2000 the New Millennium.* ieeexplore.ieee.org, 263–272.

[52] National Academies of Sciences, Engineering, and Medicine, Division on Engineering and Physical Sciences, Computer Science and Telecommunications Board, Policy and Global Affairs, Board on Higher Education and Workforce, and Committee on the Growth of Computer Science Undergraduate Enrollments. 2018. *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments.* National Academies Press.

[53] Ikujiro Nonaka and Hirotaka Takeuchi. 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation.* Oxford University Press.

[54] Ory Okolloh. 2009. Ushahidi, or 'testimony': Web 2.0 tools for crowdsourcing crisis information. *Participatory learning and action* 59, 1 (2009), 65–70.

[55] A Pendleton-Jullian and J S Brown. 2016. *Pragmatic Imagination.* Vol. 1367563127. Blurb.

[56] Michael Polanyi and Amartya Sen. 2009. *The Tacit Dimension.* University of Chicago Press.

[57] Lee Rainie and Janna Anderson. 2017. The Future of Jobs and Jobs Training. http://www.pewinternet.org/2017/05/03/the-future-of-jobs-and-jobs-training/. Accessed: 2017-6-9.

[58] Katharina Reinecke and Krzysztof Z Gajos. 2015. LabintheWild: Conducting Large-Scale Online Experiments With Uncompensated Samples. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (Vancouver, BC, Canada) *(CSCW '15)*. ACM, New York, NY, USA, 1364–1378.

[59] Christian Robottom Reis and Renata Pontin de Mattos Fortes. 2002. An overview of the software engineering process and tools in the Mozilla project. In *Proceedings of the Open Source Software Development Workshop.* ics.uci.edu, 155–175.

[60] Daniela Retelny, Sébastien Robaszkiewicz, Alexandra To, Walter S Lasecki, Jay Patel, Negar Rahmati, Tulsee Doshi, Melissa Valentine, and Michael S Bernstein. 2014. Expert Crowdsourcing with Flash Teams. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology* (Honolulu, Hawaii, USA) *(UIST '14)*. ACM, New York, NY, USA, 75–85.

[61] Veronica A Rivera and David T Lee. 2021. I Want to, but First I Need to: Understanding Crowdworkers' Career Goals, Challenges, and Tensions. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW1 (April 2021), 1–22.

[62] Niloufar Salehi, Andrew McCabe, Melissa Valentine, and Michael Bernstein. 2017. Huddler: Convening Stable and Familiar Crowd Teams Despite Unpredictable Availability. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (Portland, Oregon, USA) *(CSCW '17)*. ACM, New York, NY, USA, 1700–1713.

[63] William A Sandoval and Philip Bell. 2004. Design-Based Research Methods for Studying Learning in Context: Introduction. *Educ. Psychol.* 39, 4 (Dec. 2004), 199–201.

[64] Charles M Schweik and Robert C English. 2012. *Internet Success: A Study of Open-Source Software Commons.* MIT Press.

[65] M S Silberman, L Irani, and J Ross. 2010. Ethics and tactics of professional crowdwork. *XRDS: Crossroads, The ACM Magazine* (2010).

[66] Natasha Singer. 2019. Top Universities Join to Push 'Public Interest Technology'. *The New York Times* (March 2019).

[67] Igor Steinmacher, Marco Aurélio Graciotto Silva, and Marco Aurélio Gerosa. 2014. Barriers Faced by Newcomers to Open Source Projects: A Systematic Review. In *OSS.* 153–163.

[68] Brian L Sullivan, Christopher L Wood, Marshall J Iliff, Rick E Bonney, Daniel Fink, and Steve Kelling. 2009. eBird: A citizen-based bird observation network in the biological sciences. *Biol. Conserv.* 142, 10 (Oct. 2009), 2282–2292.

[69] Ryo Suzuki, Niloufar Salehi, Michelle S Lam, Juan C Marroquin, and Michael S Bernstein. 2016. Atelier: Repurposing Expert Crowdsourcing Tasks As Micro-internships. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (Santa Clara, California, USA) *(CHI '16)*. ACM, New York, NY, USA, 2645–2656.

[70] Rajan Vaish, Snehalkumar (neil) S Gaikwad, Geza Kovacs, Andreas Veit, Ranjay Krishna, Imanol Arrieta Ibarra, Camelia Simoiu, Michael Wilber, Serge Belongie, Sharad Goel, James Davis, and Michael S Bernstein. 2017. Crowd Research: Open and Scalable University Laboratories. In *Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology* (Québec City, QC, Canada) *(UIST '17)*. ACM, New York, NY, USA, 829–843.

[71] Melissa A Valentine, Daniela Retelny, Alexandra To, Negar Rahmati, Tulsee Doshi, and Michael S Bernstein. 2017. Flash Organizations: Crowdsourcing Complex Work by Structuring Crowds As Organizations. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. ACM, New York, NY, USA, 3523–3537.

[72] Luis von Ahn. 2013. Duolingo: Learn a Language for Free While Helping to Translate the Web. In *Proceedings of the 2013 International Conference on Intelligent User Interfaces* (Santa Monica, California, USA) *(IUI '13)*. ACM, New York, NY, USA, 1–2.

[73] Luis von Ahn and Laura Dabbish. 2004. Labeling Images with a Computer Game. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vienna, Austria) *(CHI '04)*. ACM, New York, NY, USA, 319–326.

[74] L Von Ahn, R Liu, and M Blum. 2006. Peekaboom: a game for locating objects in images. *GROUP ACM SIGCHI Int. Conf. Support. Group Work* (2006).

[75] Georg von Krogh, Sebastian Spaeth, and Karim R Lakhani. 2003. Community, joining, and specialization in open source software innovation: a case study. *Res. Policy* 32, 7 (July 2003), 1217–1241.

[76] L S Vygotsky. 1980. *Mind in Society: The Development of Higher Psychological Processes.* Harvard University Press.

[77] Barry J Wadsworth. 1996. Piaget's theory of cognitive and affective development: Foundations of constructivism, 5th ed. 5 (1996), 195.

[78] M Mitchell Waldrop. 2013. Online learning: Campus 2.0. *Nature* 495, 7440 (March 2013), 160–163.

[79] Sarah Weir, Juho Kim, Krzysztof Z Gajos, and Robert C Miller. 2015. Learnersourcing Subgoal Labels for How-to Videos. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (Vancouver, BC, Canada) *(CSCW '15)*. ACM, New York, NY, USA, 405–416.

[80] Etienne Wenger. 1998. *Communities of Practice: Learning, Meaning, and Identity.* Cambridge University Press.

[81] Joseph Jay Williams, Juho Kim, Anna Rafferty, Samuel Maldonado, Krzysztof Z Gajos, Walter S Lasecki, and Neil Heffernan. 2016. AXIS: Generating Explanations at Scale with Learnersourcing and Machine Learning. In *Proceedings of the Third (2016) ACM Conference on Learning @ Scale* (Edinburgh,

Scotland, UK) *(L@S '16)*. ACM, New York, NY, USA, 379–388.

[82] Alvin Yuan, Kurt Luther, Markus Krause, Sophie Isabel Vennix, Steven P Dow, and Bjorn Hartmann. 2016. Almost an Expert: The Effects of Rubrics and Expertise on Perceived Value of Crowdsourced Design Critiques. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*. ACM, 1005–1017.

[83] Haoqi Zhang, Matthew W Easterday, Elizabeth M Gerber, Daniel Rees Lewis, and Leesha Maliakal. 2017. Agile Research Studios: Orchestrating Communities of Practice to Advance Research Training. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (Portland, Oregon, USA) *(CSCW '17 Companion)*. ACM, New York, NY, USA, 45–48.

[84] Sharon Zhou, Melissa Valentine, and Michael S Bernstein. 2018. In Search of the Dream Team: Temporally Constrained Multi-Armed Bandits for Identifying Effective Team Structures. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. ACM, New York, NY, USA, 108:1–108:13.

[85] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 493–502.

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