Developing a Circular Textile Ecosystem through Multidisciplinary Collaboration and Partnership Building

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Abstract

This paper presents a set of findings from a two-year collaboration (2023-24) funded by the National Science Foundation Convergence Accelerator program to build a circular economy for textiles in the Delaware Valley region. The primary goal of the ReSpool project was to create the technologies, processes, and partnerships needed to facilitate textile-to-textile recycling on a regional scale. As many scholars have noted, the development of circular economies requires a multidisciplinary and collaborative approach that involves stakeholders with various forms of expertise and from a range of economic sectors. Less scholarly attention has been paid, however, to the particular challenges that such diverse teams may face when attempting to coordinate across differing backgrounds, training, priorities, and objectives. Rather than describing the technical outcomes of the ReSpool project, then, this paper focuses attention on the multidisciplinary team dynamics in a context in which social scientists, engineers, designers, and textile scientists were working together on project development and implementation. Drawing on the transcripts of more than 40 team meetings over the two-year period, the paper uses social science methods of participant observation and discourse analysis to analyze how team members interacted with each other. Several key challenges arose among the multidisciplinary team, including challenges related to the development of a working definition of textile sustainability, conflicting understandings of circularity, and competing ideas regarding the appropriate scale for a circular textile ecosystem. At times, these challenges impeded the team's progress. At other times, these challenges generated useful discussion and debate that led to new understandings of how sustainability and circularity might be achieved in the textile sector. The insights and perspectives gained through analysis of this project can usefully inform the work of other multidisciplinary teams attempting to build circular economies for textiles and other products. This paper also considers the importance of partnership building across academia, industry, and government for the success of such collaborative efforts.

Introduction and Motivation

ReSpool is a transdisciplinary partnership among academia, government, industry, and nonprofit entities that was created in 2022 to develop and demonstrate a transferable model for the recycling of postconsumer textile and apparel waste into new textile products. The ReSpool project was initially funded by the National Science Foundation Convergence Accelerator program, with the aim of building a circular economy for textiles in the Delaware Valley region of the United States. Globally, 92 million tons of textile waste is generated each year, the vast majority of which ends up in landfills or incinerators (Kerr and Landry 2017). Textile waste and clothing underutilization results in an estimated $500 billion USD in lost value annually (EMF 2017). The ReSpool model has the potential to transform postconsumer textile waste into a valuable resource for the textile and apparel industry, grow skilled employment opportunities for underserved populations in a "green jobs" (Stanif-Puic 2022) sector, and contribute to sustainable regional development in the United States, Canada, and around the world.

ReSpool's research team is focused on building the technologies, processes, and partnerships needed to facilitate textile-to-textile recycling on a regional scale. Experts in textile design, textile science, mechanical and industrial engineering, and cultural anthropology lead the ReSpool team. Each of these experts has been conducting research on textile and apparel sustainability for more than a decade. ReSpool coalesces their knowledge, methodologies, and interests in a research program designed to translate academic scholarship into innovative systems, transferable technologies, community partnerships, and regional economic development opportunities.

Rather than describing the technical outcomes of the ReSpool project, this paper focuses attention on the multidisciplinary team dynamics in a context in which scholars with diverse backgrounds and expertise have been working together on project development and implementation. Drawing on the transcripts of more than 40 team meetings over a two-year period (2023-2024), the paper uses social science methods of participant observation and discourse analysis to analyze how team members interacted with each other. The insights and perspectives gained through analysis of this project can usefully inform the work of other multidisciplinary teams attempting to build

circular economies for textiles and other products. This paper also considers the importance of partnership building across academia, industry, and government for the success of such collaborative efforts.

Review of Related Work

As many scholars have noted, the development of circular economies (CE) requires a multidisciplinary and collaborative approach that involves stakeholders with various forms of expertise and from a range of economic sectors. For example, Vouvoulis et al. (2022) argue that sustainability programs, projects, and policies are often too narrow in focus and can neglect how a specific intervention might interface, interact, or connect with broader dynamics and processes. To engender a more systemic approach and more effective systemic transformation, Vouvoulis et al. advocate transdisciplinary and cross-sector partnerships. They argue that successfully addressing sustainability problems requires "a shift in problem structuring, transforming the way problems are defined into a more collaborative process that first defines the vision … and then selects the most appropriate pathway for 'getting there,' using collective knowledge and skills traversing all disciplines and scales of assessment." They further insist that "there is never only one relevant, viable path" to sustainability, which means that multiple and diverse perspectives must be included in problem-solving and that interventions must be flexibly designed to take into account new information and changing contexts.

Leising et al. (2018) focus more specifically on the development of CE, emphasizing that "when closing and slowing material loops, it is essential to include the supply chain as a whole, and to involve all parties from design and raw material suppliers to end users, service providers and recyclers, including the associated information flows" (see also Seuring and Müller 2008). They argue that "social relationships and collaboration between supply chain partners are considered key to creating closed loop supply chains" (Leising et al. 2018; Bocken et al. 2016; Green and Randles 2006; Lai et al. 2010), and that these relationships and collaborations "need to be taken into account for a transition towards CE" (Leising et al. 2018; Genovese et al. 2017; Ghisellini et al. 2016). In fact, Leising et al. (2018) define CE as a process of "connecting a network of actors in their supply chain by managing data transparency, material flows and exchanges, responsibilities, predictability and sharing benefits." This is especially true in the textile sector, which requires an "uncommon amount of cross-sectoral collaboration" for a successful CE transition due to the tremendous diversity of stakeholder perspectives and needs (Schumacher and Forster 2022, 11).

While scholars agree that cross-disciplinary and cross-supply chain collaboration is essential for the transition to CE, less attention has been paid to the particular challenges that such diverse teams may face when attempting to coordinate across differing backgrounds, training, priorities, and objectives. Notably, Elnourani and Rönnbäck (2024) cite problems of information sharing and collaboration as urgent and significant nontechnical barriers that can hold back the implementation of circularity (see also Khan et al. 2020). They find that "conflicts of interest arise when the goals or benefits sought by one party are at odds with those of another, potentially leading to competition rather than cooperation" (Elnourani and Rönnbäck 2024, 33). Specifically, they point out that "divergent considerations and different conceptions of value, where what is valuable to one stakeholder might be considered waste or liability by another," can "complicate decision-making processes and collaborative efforts" (Elnourani and Rönnbäck 2024, 33; Geissdoerfer et al. 2023).

Technology Approach

This paper draws on the transcripts of more than 40 video-recorded team meetings that took place on Zoom over a two-year period (2023-2024). Most of the meetings took place at a regularly scheduled date and time on a weekly basis during academic semesters and on a less frequent basis during the mid-winter and summer months. The automatically rendered transcripts produced by Zoom's software were reviewed for errors and corrected by a team of undergraduate research assistants beginning in 2023. The transcripts were coded for major themes once all corrections had been made, in early 2025. Meetings were recorded with the explicit permission of all participating team members. The Institutional Review Board at the University of Delaware declared this research study exempt after initial review.

Social science methods of participant observation and discourse analysis were employed to analyze how team members interacted with each other during the recorded meetings. Participant observation is characterized by "having an open, nonjudgmental attitude, being interested in learning more about others … being a careful observer and a good listener, and being open to the unexpected in what is learned" (Kawulich 2005; DeWalt & DeWalt 2002; Bernard

1994). The author utilized participant observation during team meetings, and the author's field notes (Bernard 1994), which included reflections, questions, and observations related to the team's dynamics, supplement the transcripts as data for this study. Discourse analysis was also used to analyze the transcribed team meetings. Using discourse analysis, which is the study of "language-in-use" (Gee 2011: 8), the author focused attention on the content of the language used during meetings, including the themes and issues being discussed. The author also attended to the meaning of the language used, which refers to the integration of "ways of saying (informing), doing (action), and being (identity)" (8). These two methods permitted an in-depth analysis of team member interactions, including moments of conflict and disputed meaning.

Discussion

Several key challenges arose among the interdisciplinary team. The team exhibited competing ideas regarding the appropriate product of the ReSpool project and the appropriate scale for a circular textile ecosystem. Fundamentally, these challenges related to differing approaches to textile sustainability and CE that were largely rooted in the discipline-specific backgrounds, training, and objectives of each team member.

The Research Product – How to Build a Circular Economy

The research team was awarded major funding from the National Science Foundation Convergence Accelerator program in December 2022. The team's first formal meeting took place in January 2023, during which the team discussed the ReSpool project's goals and objectives and how to align research activities with the requirements of the granting agency. The grant emphasized fast-paced translation from basic research to marketable prototype. Teams had one year to demonstrate significant progress on the translation process, with multiple, smaller deliverables along the way, including presentations to NSF program directors and consultants.

From the first meeting, there was debate among the PI, co-PIs, and graduate student participants in ReSpool regarding the research product(s) that could and should result from our collaboration and the nature of our prototype. Much of the debate stemmed from differing ideas that team members had about the appropriate scope of the project and whether the team should be building a complete CE or specific parts of a CE during this initial phase. The following excerpt from Meeting 1 illustrates the competing ideas that circulated among the group:

> Textile Designer: … I feel like the product that we're creating is not solely a fiber-based textile product. It's actually a, um, you know, an educational platform. It's a supply chain. It's not just the textile product. So how do we explain that? In five sentences?
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> Cultural Anthropologist: There's multiple sort of deliverables, right? There's the actual ecosystem model itself. There's the kind of recycling supply chain. There's the production system. There's the jobs program and training platform. And then there's a whole … There's machinery, right? That [multiple team members] have all been involved in developing. There's the materials, right, the fibers and materials, and then maybe also soft goods and mulch mats, and like, there's all kinds of things that could be products that emerge from this. This is the real challenge, or where I keep kind of spinning my wheels, and I'm just, I'm curious if I may be alone in this, so I just want to voice it to see what others think, but where I'm sort of spinning my wheels is when the NSF asks us, when the NSF project managers ask us who are your end users, or what's your prototype going to be, then I'm like, "Well we have about 50 prototypes. At what scale are you, do you want us to talk about prototypes, you know? Do you want the machine? Do you want the ecosystem? Do you want, like, a purse? What do you want, you know? And, so, in that sense, I don't know if we're different than other project teams in that regard, or if, in fact, you know, this is going to end up being a common struggle for people because we're trying to address huge problems. And, so, you're going to have multiple components that are part of those solutions.

In Meeting 5, a similar debate arose, as the team continued to hone ideas about what prototype to propose to the NSF program directors and consultants in a meeting that was quickly approaching. The mechanical engineer on the project framed the problem as follows:

> Mechanical Engineer: For me, like, I always come back to, like, either, what is the physical system we're building? What is the organization of people or labor that we're creating? Or you could think of, like, a supply chain. Like, I think of it in terms of product-service-system. Right? So that, like, what product are we creating? What service are we like providing for you or your business? What system of labor, what system of people or system of suppliers? What's this like? That's how I think of it. And so that's what I'm telling you is, like, because there's certain things that they need that I cannot fulfill. You know, like, if they need things with regulations and policies, like, that's great. But, like, that is not something I think our team is trying to address. Do you know what I mean?

Varying perspectives on the appropriate research product derived in many ways from the diverse disciplinary backgrounds of the research team participants. In Meeting 5, the mechanical engineer explicitly defines her problem-solving approach and delineates her expertise for the group. Her training and background are in both mechanical and industrial engineering, which she renders as a form of expertise in systems development for delivering specific products or services. Her comment, "there's certain things that they need that I cannot fulfill," refers to aspects of building a CE that lie outside of her areas of expertise (i.e., developing and promoting policies that require or incentivize circular and closed-loop systems). (In this meeting and in others, the team talked about the fact that regulation might be needed in the textile sector in order to transition fully to the CE model.) As illustrated in the quotes above from Meeting 1, the cultural anthropologist, in contrast, advocated broad-based discussion of all of the parts that a CE might entail, reflecting her training as a social scientist accustomed to approaching and assessing social problems on a systems level.

The discussion of an appropriate prototype continued throughout the first year of the project, punctuated by moments of coalescence and coordination. As of Meeting 12, for example, the group had agreed on a new technology, the recycled post-consumer fibers resulting from that technology, and a set of materials created from the recycled fibers as appropriate prototypes. The combination of these three prototypes would highlight the expertise of the mechanical engineer, textile designer, and textile scientist and illustrate multiple steps in a circular supply chain. The discussion of these prototypes in Meeting 12 unfolded as follows:

> Cultural Anthropologist: I think, last week we just talked about … that our prototypes are going to be the shredder, the fibers themselves that result from the shredding process, and a set of materials, possibly woven and non-woven, that can be made with some of the fibers that are shredded. Does that sound correct to everybody else?
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> Mechanical Engineering Graduate Student: Definitely.
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> Textile Designer: And then we have some kind of visualization with a map of where we're gonna go with the more educational and upskilling stuff. You know, we show that we have these parts, but then that, like, there's the overall that we will do in Phase 2 to truly be an ecosystem. What do you think about that?
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> Cultural Anthropologist: Yeah, there's a whole range of components, parts, processes that we won't be prototyping this summer. And so, yeah, I think that's a great idea to have some visualization of what we envision an ecosystem requiring, and what parts of that we've been able to prototype so far.

In this exchange, the textile designer, who is also the project PI, emphasizes once again that the idea of a CE requires holistic thinking and a broad view of what the system might eventually entail, including the need for upskilling workers. Both an artist and a social scientist, the textile designer expressed in this exchange a set of concerns about the possibility of losing sight of the bigger picture if the team's focus was on a narrower set of product-oriented deliverables. This concern was reinforced by the cultural anthropologist, who took the opportunity to echo the textile designer's words and encourage ongoing dialogue about the full "ecosystem" that comprises the CE. Such tensions regarding the appropriate product of the research continued to emerge in team meetings throughout the life of the grant and especially in the context of periodically reporting progress to the funding agency.

Questions of Scale, Sustainability, and Circularity

In addition to the difficulties the team experienced in identifying the appropriate research product for the project, a noteworthy axis of debate throughout the NSF funding period had to do with the appropriate scale of the research product. Scale here refers to a "relational and comparative" practice by which claims regarding attributes such as size, distance, number, and quality are made and evaluated (Carr and Lempert 2016, 3). Similar to the debates regarding the research product, a divide between the team members who have expertise in engineering and those trained in design and/or the social sciences emerged in multiple meetings around issues of scale.

In the first meeting, the terms of this debate were already being set, as illustrated in the following excerpt:

> Textile Designer: … I keep thinking, "Well, how small can I get instead of this huge big innovation?" You know, how small could this be, for example. I think of the way we recycle … How could we recycle textiles in our home? So when I think of [the shredding technology developed by the mechanical engineers], I also think of scaling up to maybe Goodwills around the country, but also scaling down to household level.
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> Mechanical Engineering Graduate Student: I think the idea of having something in your house, it's very good but maybe it would be too expensive for the person to afford a machine like that, and the return for that person to use the shredder material. I don't think it would be that big. So maybe at first we would be focusing on bigger companies.

In subsequent meetings, similar conversations unfolded and the reasons for these two differing perspectives became clearer. The textile designer on the team placed a high value on building new kinds of personal relationships between consumers and their clothing, such that a small-scale intervention could allow individuals to see the potential for new uses for old clothing. Ideally, in her vision, a personal textile shredding machine could be utilized at the level of households to generate materials that consumers themselves or local businesses could use to create new textile products. The engineering co-PI and graduate student expressed concern with small-scale interventions given the projected cost of the technology, limited returns on investment (in terms of both the engineering labor that had gone into developing the machine and the return that a household might reap), and limited impact across textile supply chains. In the second meeting, team members explored these differences as follow:

> Cultural Anthropologist: I hear two different directions in how we're talking about this project. One of them is a kind of industrial model of providing a mechanical recycling process that can result in materials that can be put to a lot of different uses. And in that model, we might be developing the technology that allows a variety of industries to incorporate a higher recycled fiber content or recycled material content into the products that they themselves likely would develop and market. Or maybe we might prototype that to demonstrate for them how they could manufacture and retail, or manufacture and market some of these products. That's one model that I'm hearing … The other model that I hear is something that is much more localized, and is much more a form of, like, community engagement. And almost like individualized making and production. Now it doesn't have to be that. But it sounds like that would be a sort of starting point … .
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> Mechanical Engineer: What I am struggling with is, are we like, I struggle with the idea that we're going to work with Goodwill and give them a technology, but not tell them, like, give them, like, an idea of what textile and products to make to bring in revenue, because they are all about employing people. And so I think I'm worried about working on something that doesn't have a known end product that can make money, because somehow we gotta pay the people that, I mean, Goodwill is all about employing people. … And so I think that's my 100% main concern, is that I feel a little bit worried about just making a process without clear end products in mind, because that will inform how we choose to refine this process. Right now, we're like, "Yes, we're going for fibers." But also, you know, fibers for a landscaping company. They might have different concerns than fibers for upholstery. … I don't like the idea of just making a process with no end product in mind. It's because I feel like nobody will care unless we get the economics to work out.

The mechanical engineer's concerns regarding economic feasibility were practical matters that the team had to take into consideration throughout the project. The team's partnership with Goodwill meant that the technology and processes developed for textile-to-textile recycling had to, at the least, work within Goodwill's non-profit model. Whether the machine could also be developed for small-scale, home-based use was a concern that the textile designer had, but it never emerged as the team's sole focus. Instead, the team moved forward with a model of "scaling up." The engineers worked to increase the volume and speed of the mechanical textile shredder and the textile designer

and textile scientist and associated graduate students worked to develop textile prototypes to demonstrate scalable applications that used maximum recycled fiber content. In part because of the requirements of the funding agency and in part because of the practical matter of economic feasibility, the team advanced its objectives in line with an industrial model of textile-to-textile recycling.

Importance of Networking and Partnership Building

Another reason that the team advanced an industrial model of CE has to do with the objectives of partner organizations that joined the project through a process of networking and communication over the two-year funding period. Goodwill of Delaware and Delaware County, a key partner in the project from the earliest stages, had specific aims. These aims included a need for textile-to-textile recycling technologies and processes that could handle several thousand pounds of post-consumer textiles each month. Other partners who joined the project in the first stages, including Philadelphia-based apparel and home goods brands, needed a steady supply of recycling inputs to facilitate product development, manufacturing, and marketing. Government partners, including Delaware's Department of Natural Resources and Environmental Control, envisioned a state-wide system of post-consumer textile collection that could feed into the processes that ReSpool's academic team was developing. The needs of partner organizations, as well as the perspectives of other potential end-users and stakeholders, were assessed via an interview process in which the academic team gathered qualitative data from 41 professionals working in the fields of waste collection, recycling, fashion design, fashion sustainability, fashion retail, home goods design and retail, textile manufacturing, materials development, government policy, and economic development. By prioritizing user-inspired and applied design thinking (Brown 2008), the research team was able to tailor its aims and activities to the needs of community partners.

Conclusions and Recommendations

Elsewhere, Thomas (2020) has described a structural divide within the fashion industry that leads industry professionals to adopt differing models of environmental sustainability. "People who perform different kinds of work within the fashion industry are socialized through formal education, work experiences, and involvements with broader social and cultural movements into differing interpretations of and practical orientations toward sustainability," writes Thomas (2020, 718). According to Thomas's study, the two main categories into which fashion industry participants fall are 1) business managers, and 2) designers. "These categories," again citing Thomas (2020, 718), "do not exhaust the diversity of positions and perspectives within the industry and are not meant to suggest that individuals could not occupy multiple positions over time." Rather, these groupings are based on "the concerns, influences, dynamics, and demands" that define how fashion professionals interpret and carry out their work. As a classification scheme, the divide between business managers and designers is helpful for understanding what sustainability means for differently-positioned fashion industry participants.

People working on the business side of fashion (e.g., supply chain managers, brand managers, compliance managers) "tended to describe sustainability in terms of the measurement and management of the usage of scarce resources." People working as independent fashion designers or in design-centered roles at brands and retailers, in contrast, "tended to characterize sustainable fashion as involving hands-on, craft-based processes of design and production" (Thomas 2020, 718). These two definitions are, in many ways, incompatible, and can lead to tension within fashion organizations. They also result in different practices of sustainability. The study found that business managers tended to focus their work on "short-term and incremental fixes that conformed with entrenched business logics and workplace demands" (718). Designers, on the other hand, had questions about whether large-scale production systems could ever be truly sustainable. Independent designers focused their efforts on building social relationships across supply chains, and designers employed at larger firms sought ways to interact with materials and understand how the material properties could translate into apparel that would be used and cared for longer by consumers. Values of social closeness and durability thus characterized designers' approaches.

A similar divide existed among members of the ReSpool team during the NSF funding period. Rather than business managers, however, the team incorporated engineers. And rather than solely designers, the team incorporated people trained in design as well as the social sciences. Nonetheless, the contours of the divide and what was at stake for each party strongly resembled the divide that Thomas (2020) has described between business managers and designers in the fashion industry. The engineers on the ReSpool team valued working with existing systems of materials procurement, design, and production, perceiving an important opportunity to replace new materials with recycled

ones. The engineers also placed emphasis on the economics of this potential substitution, understanding that solutions that are not scalable to an industrial level are unlikely to achieve the desired results because of the costs involved. Meanwhile, the designers and social scientists on the team sought to reimagine recycling processes and apparel supply chains, often at smaller, localized scales. These differences were not merely the result of the different personal biographies or identities of the team members. Rather, the differing perspectives espoused by ReSpool team members also matched up with patterns that have been documented across the fashion industry. These patterns are exhibited in accordance with the types of expertise that people have and the type of work that people do on a daily basis.

At times, the challenges described above impeded the ReSpool team's progress. At other times, these challenges generated useful discussion and debate that led to new understandings of how sustainability and circularity might be achieved in the textile sector. For example, the team ultimately agreed on appropriate prototypes that could be useful at various scales of recycling and production. The team also agreed that their efforts should be ratcheted to a regional scale, rather than a global scale (á la an industrial model) or a local scale (á la the textile designer's vision of personalized interventions). A consensus emerged around the idea that regional interventions – those circumscribed by geography to limit transportation of materials, improve environmental outcomes, and encourage state and community investment – were ideal not only for the ReSpool project, but also for CEs more generally (Thomas et al. 2025). Consensus on these issues enabled the team to make significant progress toward its goals during the NSF funding period and led to additional ReSpool activities funded via other sources.

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